From Interactive Reality To Curvature Interpretation of Quantum Mechanics

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赵国求／著

从相互作用实在到量子力学曲率解释

武汉出版社
WUHAN PUBLISHING HOUSE

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ISBN 978-7-5430-4053-3

9 787543 040533 >

定价：48.00元

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(鄂)新登字 08 号
图书在版编目(CIP)数据
从相互作用实在到量子力学曲率解释/赵国求著. —武汉:武汉出版社,2008.11
ISBN 978—7—5430—4053—3
Ⅰ.从… Ⅱ.赵… Ⅲ.量子力学—曲率—研究 Ⅳ.O413.1
中国版本图书馆 CIP 数据核字(2008)第 162425 号

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出　版:武汉出版社
社　址:武汉市江汉区新华下路 103 号　　邮　编:430015
电　话:(027)85606403　85600625
http://www.whcbs.com　　E-mail:wuhanpress@126.com
印　刷:武汉中科兴业印务有限公司　　经　销:新华书店
开　本:787mm×1092mm　1/16
印　张:31.25　　字　数:479 千字　　插　页:3
版　次:2008 年 11 月第 1 版　　2008 年 11 月第 1 次印刷
定　价:48.00 元

Foreword

The interpretation of the wave function is one of the two fundamental questions in understanding the foundations of quantum mechanics (the other is the so-called measurement problem). Ontologically, there have been two ways of interpreting quantum mechanics, based on the assumption of particle ontology or wave ontology. The most prominent particle ontology interpretation is the so-called Copenhagen interpretation (the square of the wave function indicates the probability of the appearance of a particle, or many particle, with certain physical properties, or of a physical process [such as a decay, or a transition, or a pair creation of annihilation]). Of course, the particle in the Copenhagen interpretation is not the Newtonian particle with a fixed and permanent existence, but, rather, a statistical existence. As to various forms of wave ontology interpretation, conceptually, all variants of this school has to assume the existence of some sort of substantial wave, and this has created an almost unsurmountable difficulty: wave of what? Or what is the material or substantial carrier of the wave? Readers who are familiar with Max Jammer's book THE PHILOSOPHY OF QUANTUM MECHANICS know the record of miserable failures by the earlier attempt in this direction. The most serious difficulty, among many others, is related with the dimensionality of the wave function. All substantial wave must exist in four dimensional physical spacetime, but a wave function for any physical system other than one particle ones, must have its dimension more

than four. That is, the wave function exists only in a phase space rather than in the physical spacetime.

The heroic, or audacious, attempt of the project, the curvature interpretation of quantum mechanics (a variation of the wave ontology interpretation), pursued and summarized in this book cannot avoid facing this difficulty. Thus my first impression of the project was completely negative: how could such a project outrageously ignoring fundamental conceptual constraints could have any future? The central concept of the project is the curvature of the wave, which carries all the causal power in any quantum systems and thus the explanatory power in the project. But the dimensionality difficulty has indicated that it cannot be consistently conceptualized within the existing metaphysical framework of the physical world and thus cannot be integrated into any existing conceptual framework of physical theory.

When I carefully re-read the book, however, my impression has gradually changed when I consciously put the project into a bigger picture or framework, a framework including the notions of scientific explanation and structural realism.

In terms of scientific explanation, which, according to Mary Hesse, is only a metaphorical redescription of the phenomena to be explained, the curvature interpretation certainly has enough explanatory power and thus is not incompatible with the spirit of scientific explanation since the notion of curvature is an easily understandable and acceptable metaphor.

But the most important philosophical justification comes from the implication of structural realism, which in fact is my own favorite project. According to my version of structural realism, the ultimate ontology in a physical theory is not presumed metaphysically or speculatively or based on any existing experience, but has to be constructed on the basis of the structural knowledge involving the hypothetical ontology. The chances for the curvature interpre-

tation are, although quite remote indeed, that a notion of a substantial wave can be consistently constructed from all the structural statements involving the wave integrated within the framework of the curvature interpretation without any direct conflict with the existing notion of substance. How could this be possible? The only possibility for achieving this without any logical difficulty is to acknowledge a new metaphysical status of the substantial wave constructed within the curvature interpretation. That is, the substantial wave constructed has to be accorded as a new form of existence, a new category of natural kind. It certainly differs from traditional wave. But this difference should not be taken as an insurmountable barrier for its acceptance. The particle in the Copenhagen interpretation also differs from traditional particle.

Chances for successfully attaining this goal cannot be ruled out in principle, although in practice it requires heroic effort and substantial inputs of time, energy, organizational and financial resources. But if, a very big "if" indeed, this can be achieved, and if, an even bigger "if", the curvature interpretation can rule out some existing interpretations of quantum mechanics, and incorporate others into its framework and prevail, that is, if it can be accepted as THE interpretation of quantum mechanics, then the achievement is far more than an interpretation in any conventional sense, but involves a discovery of a new form of existence. An achievement that would enjoy a status equal to the achievement of the discovery of the electromagnetic field as a new form of existence, which is different from the "only" form of the existence known to human being then, namely the Newtonian particles or ponderable matter; or to the achievement of the discovery of confined quarks and gluons, which differ from all other forms of physical existence, namely they cannot have any separate existence, or in the jargon of the high energy physics community, have no asymptotic states.

This is not a book for students or practicing physicists. But ambitious philosophers and speculative physicists might find it highly stimulus, stud with numerous insights, which can, at least, be used to construct a consistent and integrated framework. More serious scholars might be lured to have further exploration along the line opened by the project pursued in this book. For such a small amount of serious readers, I recommend this book with somewhat ambivalent feelings revealed in the above lines.

[illegible] (Boston University)

June 18,2008

序　一

对波函数的解释是理解量子力学基础的两个基本问题之一(另一个问题是所谓的测量问题)。从本体论来说,解释量子力学一直有两种方法,它们都基于对粒子本体论或波本体论的假设。最著名的粒子本体论解释是所谓的哥本哈根解释,即:波函数的平方表示具有一定的物理特性,一种物理作用中的单粒子,或多粒子出现的概率(如衰变,或跃迁,或湮灭形成电子对等)。当然,哥本哈根解释中的粒子不是牛顿所说的永恒的固定粒子,而是一种统计上存在的粒子。至于各种各样的波本体论解释,从概念上说,这个学派的所有分支都不得不假设某种物质波的存在。这又产生了一个几乎不可逾越的困难:什么物质的波?物质波的载体又是什么?读过马克斯·雅默著作《量子力学的哲学》的读者就熟悉早期朝这个方向努力的惨败记录。其中最严重的困难与波函数的维数相关。所有的物质波必须存在于四维物理时空,但对于任何不是一个粒子的物理体系,体系的波函数必须有四个以上的维数。也就是说,波函数只存在于一个相位空间而不存在于物理时空。

本书勇敢而大胆的研究课题:量子力学曲率解释(波本体论解释的演变)的求证和总结,也毫不例外地面对着这一困难。因此,起先我对这个研究课题的印象完全是否定的:如此简单地忽视基本概念制约的研究课题能有什么前途呢?该研究项目的中心概念是曲率波,它传达了任何量子体系中的所有因果链条,并担负这一研究中所具有的解释力。但是,维数的困难已表明了,在物质世界现存的形上框架内,它不能与已有概念形成协调,因此不能与物理理论的任何现存概念框架相结合。

然而,当我仔细地多次反复重读这本书之后,当我有意识地把这

一研究课题放进一个更大的图像或框架中去的时候，我的印象逐渐改变了。这个框架包括了科学解释和结构实在论思想。

按照科学的解释(用玛丽·赫西的话说，科学解释只是对要解释的现象作比喻性的重新描述)，曲率解释一定有足够的解释力，因而与科学解释的精神不是不相容的，因为曲率是一种很容易理解和接受的比喻。

但是，最重要的哲学理由还是来自结构实在论的实质，这也是我自己最为偏爱的研究课题。按照我提出的结构实在论版本，物理学理论中最基本的本体论，不是从形上或推测的角度进行假设，也不基于任何现有的经验，而是必须在一定前提下，由本体论结构知识进行构建。在曲率解释的框架中，物质波可以毫无直接冲突地与现有物质观相结合，并在所有结构陈述中不断地构建。这就是曲率解释可能成立的基础，尽管它任重而道远。它之所以可能，还因为在没有逻辑困难的情况下，达到这个目的唯一的可能性只是承认曲率解释构建的物质波是一种新的形上形态。也就是说，所构建的物质波必须符合一种新的存在形式，一种新的自然本质的类别。它肯定不同于传统的波。但这种不同不应该被看作接受它的不可逾越的障碍。哥本哈根解释的粒子不是也不同于传统的粒子吗?

原则上不能排除成功地达到这一目标的可能性，虽然在实践上它要求勇气和艰辛的努力，要求时间、能力、组织资源及财务资源的实际投入。但是如果(的确是极大的“如果”)这个目标能够达到，并且如果(一个更大的“如果”)曲率解释能够排除某些现存量子力学解释的弊端，并把其他解释的优点纳入其框架之内，即：如果它能够作为量子力学解释被接受，那么其成就将远远大于任何传统意义上的解释，并具有发现一种新型存在的意义。作为一种新的存在形式，其成就将等同于电磁场的发现！电磁场曾作为一种新的存在形式，不同于其时人类已知的“唯一”的存在形式，即：牛顿的粒子或可观察的物质；或者说，其成就将等同于夸克和胶子的发现！夸克和胶子不同于物理存在的所有其他形式，用高能物理学共同体的行话来说，即：它们不能有任何部分的独立存在(夸克禁闭)，或没有渐近的状态(渐近自由)。

本书不是教科书，也不是为实用物理学家写的。但有抱负的哲

学家和有思想的物理学家可从中发现极大的激励和深远的洞察力。它至少可用来构建一种协调的完整框架。它可以吸引严肃的学者，沿着本书所开创、所追寻的研究路线去进一步深入探索。我怀着在上述序言中流露的复杂心情为这样的一些严肃的读者推荐这本书。

曹天予 2004年6月18日

（美国·波士顿大学）

序　二

量子力学各种解释的争论由来已久，至今难有定论。见诸于世的解释至少有十数种，较为流行的也有六七种。每一种解释都有其长处和短处。实际上不管何种解释，只要能自圆其说，都应引起重视，深入研究，都应有其一席之地。赵国求的相互作用实在与量子力学曲率解释就是一种值得关注的新创见。

认识赵国求的时间并不长，但深为他的深入钻研和坚韧不拔的探索精神所感动，更为他的创新思想所吸引。赵国求的量子力学曲率解释，从一个全新的视角考查了微观世界微观客体的运动状态。他认为物质波波函数描述了我们通过物质波波长 λ 为微观客体建构的“形”的变化规律，而“形”的变化与在“形内”找到“点粒子”的概率，是可以相互转换的。形大，“形内”找到“点粒子”的概率小；形小，“形内”找到“点粒子”的概率大。用物质波波长 λ 为微观客体建构的“形”($r=\lambda/2\pi$—相位圆半径)成了微观世界和宏观世界相互沟通的桥梁。若用曲率 $R(R=1/r)$ 描述微观客体的“表面特征”，则波函数 $|\psi|^2$ 既有曲率属性，也有概率属性。波函数是曲率波，曲率的大小表示粒子性，曲率的变化表示波动性，微观客体的波粒二重性在曲率解释中有了和谐的统一。由于曲率、概率可以在“形”的帮助下相互转换，因此，凡概率解释所能解释的现象，曲率解释则全都可以解释，曲率解释可以包容概率解释。而概率解释因“形”的缺失而带来的悖论，在曲率解释中则可以得到消除。看来，曲率解释真是一个十分有趣又十分诱人的新的解释方案。

赵国求的曲率解释是实在论的，说得更确切些是本体论的实在论。它需要自己的哲学基础。在桂起权倡导的科学共同体的帮助下，近两年蔡肖兵亦参与其中，赵国求对相互作用原理，微、宏观作用

机制，微、宏观质点抽象原则，量子概率与宏观经典概率，微观时空与宏观时空都做了十分深入精细的分析、研究工作，并在此基础上认识物质波波函数的物理意义，从而建立起量子力学曲率解释。量子力学曲率解释的本质是波函数$|\psi|^2$，描述了微观客体自身的时空特征。作者认为，微观客体的测不准是对微观客体做质点抽象和量子测量赋予的，测不准有其实在论背景。这是一个具有启发性的新视角，是现有量子力学解释所忽视或关注不够的。正因为如此，我认为相互作用实在观与量子力学曲率解释应该值得关注，也值得引起量子力学哲学界同仁进行讨论。从一个前人尚未关注或关注不够的视角，深入研究，应该会有新的东西发现。量子力学哲学尚有许多值得深入探讨的问题，对它的任何新认识，都将影响人类新精神的提升。赵国求探索的意义也许正在于此。我们对赵国求寄予希望，也对他的合作者表示赞许。我们期盼这个量子力学哲学探索的共同体在量子力学哲学解释中做出新贡献。

金吾伦

2008年6月于北京

序　三
直觉图像思维模式仍然有启发力

——为《从相互作用实在到量子力学曲率解释》作序

量子力学的“曲率解释”是多样化的量子力学解释的百花园中的一棵新苗，她正在茁壮成长。很高兴看到赵国求先生的新著《从相互作用实在到量子力学曲率解释》中英文合订版即将出版，该书无论在物理学上和哲学上都在原有基础上有了新的进展。在物理学上，新著对量子力学曲率解释思想做了进一步梳理和更加体系化的阐述，尝试性地把它应用于讨论量子测量，解释“退相干”，并讨论“规范场的物理意义和哲学意义”等新问题。在物理学哲学上，新著对“相互作用实在论”的理解大大深化了，在这个实在论的新版本中，不再仅仅停留在“现象实体”与“自在实体”两个层次的严格区分上，而是更加强调两个不同层次之间的相互沟通，“自在之物”终于可以变为“为我之物”了，从而消除了不可知论的疑难。

一、要创新就得打破常规

在与赵国求教授的交往中，我发现，他有十分丰富的想像力。他常自谦地说在科学思想上是“不安分”的，日本著名物理学家汤川秀澍说，科学的发展需要大胆的“越轨”行为来实现（《创造力和直觉》105 页），依我看，这“不安分”与“越轨”正是他的头脑里不时能冒出原创性奇思异想的原动力。在物理学和物理学哲学的研究上，他非常擅长于直觉思维和形象模型，并且以此为锐利的武器，刺探量子世界深层的奥秘。这一特点深深地吸引了我。实际上，我对赵的直觉图像思维模式的可行性和有效性的理解，经历从怀疑、抵制到接受再到欣赏，是有一个过程的。现在，我认为，赵国求先生最有特色性的

方面恰恰在于他的直觉图像思维模式。我相信，这也就是他创造力的重要源泉。进一步说，直觉图像思维模式对于科学探索与科学创新是具有普遍意义的，这应当是一个很值得研究的问题。说起科学创新，我想起一件事。记得 2003 年 3～4 月我去广州中山大学参加《张华夏先生系统哲学思想讨论会》期间，蔡肖兵博士(他是“创新”专家金吾伦教授的弟子)在交谈中对我说，他是中国科学技术大学的老大学生，原先也是学物理的。他有好几个基本功非常好的优秀同学，现在在美国从事理论物理学研究，很可惜近年来并无大的突破性进展。他认为，对于那些“正牌”理论物理学家而言，问题的症结不在于他们缺乏雄厚的科学功底和高超的数学技巧。问题恰恰在于，那些理论物理学朋友的思想太正统，结果是自己束缚自己，不敢想不敢为。对于他们来说，最最需要的是引进大胆丰富的想象和批判性思维，并且最好能够与他们的扎实功底和严密的逻辑有机地结合起来，从而让他们的潜力和优势最大限度地发挥出来。要不然，哪会有什么重大突破呢？这就是说，打破常规是创新思维的基本出发点。顺便说，在我国科学哲学学者之中，金吾伦先生是研究创新思维的专家，同时他又是“生成哲学”的创始人。我个人认为，真空量子场中的粒子由无形无象的“场物质”而创生和湮灭，这个物理学事实最适合于“生成哲学”的解释模式。我把它看作“实在论”的新形式(有别于旧的“粒子实在论”)，并且认为其中包含着活生生的辩证法，张华夏先生则是极力主张哲学上的“实体实在论”的，这就与赵先生量子力学的“实体实在论”不谋而合，两者之间存在一般与特殊的关系，可以相互为用。只不过，张偏重于哲学角度，而赵偏重于物理学角度而已。

二、创造力和直觉

最近，我重新阅读了著名日本物理学家汤川秀澍的《创造力和直觉》，深有感触。科学本身就是人类思维的奇迹，奇就奇在它能够深入物理世界的内部，达到很深很深的层次之中。西方人受到古希腊 Aristotle 传统的深刻影响，擅长于逻辑思维，然而自古以来中国和日本等东方人则擅长于直觉思维。受东方文化传统影响，汤川秀澍特别了解逻辑严密性和直觉及想象在科学家认识活动中的微妙差

别，因此逻辑推理与直觉思维的关系，是他经常考虑的问题。他根据自己科学实践的切身体验认识到，直觉思维在更大程度上是创造力的源泉(19 世纪 90 年代，脑科学经受了“右脑革命”的洗礼，也支持这个看法，请参看《右脑与创造》)。汤川抱怨道，对于年轻一代物理学家来说，片面的抽象化趋势越来越严重，理论物理学被简单地化归为“群论加上复变函数论”等纯粹的数学抽象，浪漫主义色彩越来越少了，对于创造性思维绝顶重要的直觉和想象恰恰被人忽视了。汤川反复强调说，在理论物理学的发展中，“单靠逻辑学是什么也干不成的。唯一的道路是直觉地把握整体，并且洞察到正确的东西”。(42 页)“在任何富有成果的科学思维中，直觉和抽象是交相为用的”。(93 页)他指出，与一般人的想法和了解不同，直觉图像思维并没有真正过时。依我看，这样一来，赵国求先生所钟爱的思维模式，终于在理论物理学大师汤川秀澍那里可以找到合法的存在理由和充分的根据了。

三、从怀疑到赏识

回想当年，在我们的物理学哲学课题组初次开展活动的时候，我对于赵国求教授喜欢采用“直觉图像思维”模式讨论问题是充满疑虑的。为什么这样说呢？因为按照我的想法，尽管玻尔在 1913 年发明原子模型时确实也使用过图像思维，但是自从海森伯引进了“可观察量原则”并且与马克斯·玻恩一起创建了矩阵量子力学的时候起，可视图像思维这种探索方式也就过时了，其理论价值也就终结了，从此它被远远地抛在时代的后面。这应当是不言而喻的人所共知的常识。如果连这个基本点都不承认，那么还讨论什么量子力学的哲学呢？因为按照我当时的想法，海森伯对于这些问题早就说得足够清楚的了。他指出，对于哥本哈根量子论“反实在论”的指责是不正确的，“客观实在性”概念并没有从物理学中赶出去，因为它在量子论和经典物理学中起着同样的重要作用。不过，假如我们试图透过这个“实在”背后去追究原子事件的细节，那么经典意义的那种“实在世界”就消失了，但它只是以“潜在”的形式消失在数学定律的透彻澄清之中(见卢鹤绂《哥本哈根量子论考释》，复旦大学出版社 1984 年版第 148 页)。我和王自华在写《海森伯传》(长春出版社，1999)时还特

别提到过一件标志性的事件，那就是 1924 年冬，在量子力学诞生前夕，哥本哈根共同体正好处在方法论的转折关口。那时，海森伯和克拉默斯正在合作研究“色散”问题，玻尔让他们中的每一个人准备好一份初稿，结果两人发生争执：海森伯采取玻恩的典型的公理化方式和纯粹的数学手段处理问题，彻底摆脱了物理图像模型，而克拉默斯则采取玻尔的典型的图像思维模式，处处都不忘记物理模型和物理意义，即中间过程不断需要有形象类比。那么，玻尔的态度究竟怎么样呢？结果真没想到，玻尔的最后裁决居然倒向海森伯一边。海森伯后来回顾说，这是哥本哈根第一次强调摆脱直观的图像思维模式的重要性，它将成为今后一切工作（指量子力学研究）的指导原则。这件事明显地标志着哥本哈根的方法论转向，它似乎说明那时候甚至连玻尔本人都要下决心放弃直观图像的思维方式。应当说，这些都早已经成为一切了解量子力学这门学科的人的共识，早已经成为不可怀疑的背景知识的一部分。然而，现在赵国求先生竟然站出来说，你们不敢怀疑的我来怀疑，图像思维模式照样好得很，量子力学仍然离不开它！首先，我真佩服他的敢于反正统、反常规、反潮流、反权威的创新勇气，但是另一方面我又真是怀疑，他是否在号召大家“回到牛顿去！”回到牛顿式的物理本体论（老的实体实在论）和拉普拉斯式的严格决定论，也许是在开倒车，要倒退到爱因斯坦之前的物理学去。他要对不确定性关系作“决定论解释”（不仅仅是实在论解释），更加使得我大吃一惊。我真担心，他是否比爱因斯坦还要相信严格因果性和严格确定性，是否想要教训“上帝不要掷骰子”，想要根本取消量子世界的不确定性。我真担心，他是否过分钟爱朴素实在论，是否犯了机械唯物论的毛病？在这里，我只是把自己当年的亲身感受痛痛快快地说出来罢了，我相信当时王贵友教授对此肯定深有同感。

当然，现在对我来说这一切都成为过去，我在《物理学的新神曲》序言中就已经认识到并且具体说明了“量子力学曲率解释”的种种优点和特殊价值了。简要地说，那是：①用“曲率”刻画波函数的物理和几何特征比“概率”更加深刻；②曲率解释消除了“负概率没有物理意义”的困难；③曲率解释描述粒子内禀波动通过相互作用在时空中的投影。学术上的相互了解和理解是需要一个时间过程的。实际上，

在课题组内部，是经过多次交锋和商讨，大家才从各自的原来过分强硬的立场上退让下来，也就是放弃了独断论的说话方式，放弃了实际上不该坚持的非本质的方面，但是这并不意味着放弃各自的最核心的论断，相反它是变换成更加合理的方式坚持了下来。赵国求先生面对形形色色的批评意见，通过不断调整辅助假说捍卫了核心观点，通过从不同角度的反复说明来澄清自己基本观点的实质性内容。

四、量子力学解释的多元化

在科学哲学中，我赞赏多元主义方法论。诚如费耶阿本德所说，每一种科学理论、科学方法都有优点和缺点。Anything goes 这个著名口号的真正意思常常被误解了，它并不表示每一个科学家可以乱搞一气、怎么都行，而是表明不同观点的科学家各行其是、各有各的道理。我想，对于科学解释也应该是这样。因此，至今我仍然极愿意欣赏每一种量子力学解释的优点和合理成分。正是在这个意义上说，我是一个方法论的多元主义者。除了本书重点推举的曲率解释之外，这里可以挑选几种最有代表性的量子力学解释来分析一下。例如：

(1)哥本哈根正统解释，尽管经过 3/4 世纪的风风雨雨，它仍然是各种不同解释的基本的出发点和参考系。你可以不接受那种认为量子力学是对于单个系统的完备描述的“强解释”，但是很难不接受认为量子力学是描述全同地制备出来的系综的“弱解释”和诸如此类的“统计解释”。通过在课题组内部的特别是与赵国求先生的多次交锋，我从“强解释”的武断立场上退了一步，不再断言“强解释＝量子力学的内在要求”；也不再断言“概率是自然的终极本性＝量子力学的内在要求”。赵国求先生也不再坚持曲率解释是排他性的、唯一正确的、独一无二的合理解释了。转而承认概率解释的合理部分，并纳入曲率解释之中，建立起曲率与概率的对应联系，一场观点上的严重对立终于得到了化解。我认识到，应当把哥本哈根解释的科学成分和哲学成分严格区分开来。现在我只敢断言，“强解释”只是多种可能解释中的一种。话虽如此，退让是有底线的。你可以不相信概率是自然界终极的内在本性，但是你不能不相信玻恩所说“世界是因果与机遇联合统治的”。两个要素缺一不可。你可以不接受冯·诺依

曼的“投影假设”那样的特别设计的假设，但你恐怕不会拒绝他关于“量子世界处在因果性与统计性之间”的看法。你可以像爱因斯坦那样，批评“互补性构架”在解释问题时的确是有点像“舒服的软枕”（指面对诸如粒子与波的矛盾冲突，在妥协中求太平，所谓绥靖哲学），却不能否认用“互补性”所作的概括确实能够对量子领域的事实作“最后的详尽描述”，例如不能否认一对共轭物理量之间确实有“互斥又互补”的关系存在。尽管玻尔的现象整体论只是表层的，却不是错误的。我们也很难批评“纯粹的量子态是客观的，却是潜在的而非现实的”那样的论断有什么不对。当然，玻尔的解释确实有缺点，赵国求先生等人牢牢抓住不放的“本体论图像不明晰，只针对可观察量而非针对实在的”等等，确实不是没有问题。

(2)这正是玻姆的量子势因果解释和本体论解释能够兴起的原因。玻姆勾勒了关于新型量子场和粒子之间关系的清晰的本体论图像。量子场是整体全息相关的，量子势是不随距离而衰减的，它的波函数的“形式”（它携带着能够对量子场全局起控制作用的“主动信息”量）才是根本的，因此“远程关联”现象可以得到合理解释。量子场、量子势＝粒子的引导条件，量子场＋粒子（仍然）＝因果性的。玻姆的本体论形式的整体论比玻尔的现象整体论更加基本，因为它具有可以直观理解的形象模型和可操作、可运作的具体机制。它的优点是，能够在附加“亚结构”之后提供单个现象模型，所受到的批评是这样所花费的代价就太大。在我看来，就重视图像模型方面，曲率解释与玻姆—洪定国的本体论解释也有相通之处。其实，曲率解释由波函数所决定的空间结构，就相当于玻姆的量子势。量子场就是空间结构场。

(3)“相对态”或者“多世界”解释被认为是一种更加精简的解释，宇宙波函数被看作唯一的终极实在，因此它显得更加简单、彻底和一贯。解释的关键在于一个类比：类比于爱因斯坦的参照系的相对性，似乎也可以悟出量子态自己的“相对性原理”，尽管在含义上有本质的区别。由被测对象、仪器与观察者所组成的复合系统处于叠加的纠缠态之中。每一个测量都只是从这个复合整体中提取其中一个成分即一个相对态而已。依我看，读者只须把相对论类比贯彻到底，只须仔细想想在相对论中，相对于不同参照系的观察者可以有各自不

同的"局域时间"和"局域长度",它们同样也是真实的(如果不信,则你可以亲自参与其中进行观测)。那么就不难理解"量子态的相对性"的真实性了。如果将这相对态加以实体化,按"本体论方式"来理解,那么就可以得到"多世界解释"。如果从观察者视角,按"认识论方式"来理解,那么又可以引申出"多心解释"来。

(4)甚至像流体力学解释那样的"坏"解释,在"隐喻"的意义上仍然具有合理性。要知道,隐喻也是一种图像思维模式,它的特殊的方法论价值正在被重新发现。近年来,隐喻和科学理论的建构以及科学哲学的关系日益受到重视(见郭贵春、李醒民等的论文)。正是这个量子流体解释的隐喻,使得我们有可能在有关"梯度、散度、旋度"的数学上的场论概念与物理场的形象模型之间建立联系。隐喻具有间接表达"只可意会,难以言传"的意义的功能。我们可以设想,流动着的"场物质",从一个等势面爬上另外一个更高的等势面,势沿着法线方向的变化率大小恰恰意味着场的强度;假如我们再设想用古代哲人所说的"理性的眼睛"来进行洞察,那么透过 Maxwell 方程组中的不同方程式就可以建构某种心理意象,它们能够表征着电磁场的"场物质"流从源头发散出来或者处在涡旋之中,诸如此类。这种隐喻或心理意象可以增强对电磁场的想像力和理解力。这里,我所采用的解释方式正是"赵氏图像思维模式",这并没有什么不合理。要知道,爱因斯坦就没有否认过广义相对论"以太",不过他指的是引力场的"场物质"。同样,我们为什么不能够想象量子场的"场物质"或海森伯的充实真空量子场的"原物质"(Urmaterie)?

总之,我认为,在量子力学中的每一种具体、个别的解释,"各有各的道理",就好像"盲人摸象"故事所说的那样,都只是摸到了局部真理,整合之后才可能有完全真理。这就是我关于量子力学解释的多元主义立场的真意。

五、直觉图像思维并没有过时

赵国求先生是非常机敏的。正当他想要对"测不准关系"作决定论解释,让大家大吃一惊而且还没有完全反应过来的时候,他动用了直觉图像思维的锐利武器向"点粒子模型"发动了猛烈攻击。诚然,"点粒子模型"确实是正统量子力学的弱点和痛处,那是不堪一击的,

因此这种证伪手法是非常高明而且十分有说服力的。在这一点上，我不得不接受他的论证。于是，我就倒过来帮助他说了话，因为我想起日本物理学家坂田昌一在其《科学哲学论文集》中也主张，点粒子模型是造成正统量子力学诠释体系混乱和悖论的根本原因。然而，在一开始，当我听到赵先生津津乐道地大讲电子的形象模型时，什么小球啊小球啊，半径呀曲率呀的，我心里又犯嘀咕，怀疑他是否又回到牛顿的经典力学那里去了。然而，赵先生确实非常善于抓住一切强有力的有利实验证据。这就是：美国实验物理学家霍夫斯塔特对中子和质子分布半径的实验检验及其他人对电子分布半径的测试，其实验数据与特征长度都符合得相当好。真叫我无话可说，我算是服他了。

我觉得，不同的物理学哲学研究者可以排列成一个"家族相似"的谱系（Wittgenstein 的说法）。按照每个成员的思想中物理学成分和科学哲学成分比例的差异，产生不同的色调。例如，假如将关洪、洪定国、赵国求、桂起权、王贵友、金吾伦、张华夏诸教授排列起来形成一个谱系，那么大致可以说，哲学成分在递增，物理学成分在递降。当然，这不是绝对的。比如，洪先生对于哲学的考虑比关先生更多，却并不代表他对于物理学的关注更少。又如总的说来，我的科学哲学成分比赵先生多，而物理学成分比他少。然而，我在物理学思想史方面却要比他更为熟悉，但他在科学实在论等哲学问题上却比我考虑得更多、更为深刻。

值得一提的是，在"相互作用实在论"问题上，我认为目前这本《从相互作用实在到量子力学曲率解释》是有新的突破的。说句老实话，对于赵先生的"实在论"，在一开始我并不看好。他说"说月亮不看它的时候就不存在＝主观唯心主义"，我说这样的说法太笼统，在现象层次确实有"不看它就不存在"，不是唯心主义，因为只有对量子客体进行观察、测量才能产生量子现象，这并不意味着否定量子客体的存在。在经过课题组激烈争论和讨论之后，赵先生回到家里也许又度过了几个不眠之夜，他终于得到"相互作用实在论"。过后，他清楚地划分了两个层次：现象实体与自在实体。对于这些看法，我当然是举双手拥护的。通俗地说，月球没人看时作为"月亮"就不存在——这说明"现象实体"对观察的依赖性；但是"月亮"即使没人看，

作为月球仍然存在——那说明“自在实体”的客观性。不过，在这一问题上，相当一段时间我还是有所保留，尚存疑虑的。赵先生有一句很喜欢说的话是：“月亮不看它的时候，不是不存在，而是不知道”（着重号表示他讲话时有点得意的语气），用它来通俗表示两个层次之间的严格区分。尽管我不得不接受这些看法，但是仍然对此不够满意，尤其是对于那个有点刺耳的“不知道”感到十分不满意。原因在于，康德早就说过，“物自体”不是不存在，只是我们不知道。因此，我对于“相互作用实在论”的原有表达形式，总是担心它与“不可知论”划不清界限。现在好了，本书一方面从哲学角度说明了，“自在实体”与“现象实体”既不能直接混同又不能绝对割裂开来。另一方面又从物理学角度说明了（例如从德布罗意导波到康普顿物质波）“自在实体”可以不断转化为“现象实体”，前者正是通过后者才表现出来。使我高兴的是，我似乎觉得“相互作用实在论”一下子从康德水平提升到了恩格斯水平上去了。

最后，我想说，其实在量子物理学研究中，直觉图像思维的传统并没有完全中断，这种思维模式至今仍然有启发力，只是随着具体情况的不同它随时需要改变表现形式。正如美国科学史家 A. I. 米勒在《科学思维中的意象——创造 20 世纪物理学》(1984)一书所述，心理意象直观图无论对于阐明科学家创造性思维的特征或者是帮助读者理解消化深奥的现代物理学理论都有极大的作用。1932 年海森伯在讨论复合中子与核内质子之间的交换力时，就使用过心理意象直观图，这是对于科学家的心理意象的一种高级的抽象概括和形象化描述，比卢瑟福—玻尔的直观模型图更为抽象。海森伯的意象直观图最终演变为粒子物理学中通用的费曼图，它能够把粒子之间的相互作用产生与湮灭过程简洁而形象地刻画出来。

1948 年，费曼在波科诺会议的报告中，首次公开了奇妙的费曼图，大家被它的快速高效功能所震撼（美·阿伯拉罕·派斯《基本粒子物理学史》，关洪等译，武汉出版社，2002 年第 580 页）。每个费曼图对应一个数学表达式，它们加在一起就给出 S 矩阵。直线＝电子；波浪线＝光子；连接＝相互作用。借此，费曼能够免除数以百计的烦琐代数计算，并且能够一下子就把可恶的无穷大分离开来。戴森的评价是：“费曼从来不用写下方程就把解从头脑中写出来了，他对事

物的发生过程有物理图像。而这图像只要很少一点计算就能让他得到解，难怪他让那些在解方程中度过了一辈子的人感到为难。一般人的头脑是分析型的，而费曼则是图像型的。”（美·米切奥·卡库等《超越爱因斯坦》，陈一新等译，吉林人民出版社，2001 年第 64 页）费曼图能使他比那些轻视图像思维并且迷失在计算复杂性之中的人看得更远。

有趣的是，本书作者赵国求先生使得在量子物理学中几乎被人遗忘的更朴实的直观图像思维方式重新恢复了青春，重新开发出它的方法论功能，这一点本身就富有认识论意味，是很值得引起读者的关注和深刻思考的。

桂起权

2008 年 6 月 26 日

目　录

前　言

《从相互作用实在到量子力学曲率解释》中英文版与读者见面了。这部专著既是我40余年研究物理学哲学的心血结晶，也是由桂起权教授牵头的《物理学哲学研究》课题成果的进一步深化、发展与完善。几十年来，我一直将我的研究界定在“物理学哲学”上（有人说是“物理学味很浓的”科学哲学）。一方面，这是由研究的内容所决定的；另一方面，我也确实小心翼翼地在物理学和哲学之间寻找自己的生存空间，希望能为物理学家和哲学家提供有益的启示和思考。

既然是研究物理学哲学，那就必然同时与物理学和哲学相关。研究中必然会深入到物理学和哲学深处，寻找我们的猎物和目标。必须声明，我们对现有物理学中公认的成果从未有过否定之意，但我们也从不放过在物理学和哲学之间留下的空隙中播上自己的种子。期望得到物理学家和哲学家两方面的呵护，在种子的生根、发芽、成长、壮大中能给世界带来一丝清新。

到目前为止，我的物理学哲学研究经历大致可分三个阶段。第一个阶段是大学读书时期到文化革命结束。我从小就喜欢打破沙锅问到底，对自己感到新奇的东西，总有强烈的吸引力。当年我就读于华中科技大学。大学二年级，我对相对论和量子力学发生了浓厚的兴趣，尤其是对相对论和量子力学中尚属讨论的问题着了迷。文化革命一开始，我就因“重专轻红”入了另册。后来在抄家的过程中，从我的日记和所写的大量诗词中又发现我有成名成家思想。我被关入牛棚，加强思想改造。不过，没有多久，我就被定性为“虽受封资修毒害太深，但还不是阶级异己分子”，因而被释放了，此后再也无人问津。上天赐给了我读书的好机会。记得那时学校整栋教学大楼，只有我孤灯长明。在这一时期，我自学了柏格曼的《狭义相对论导论》、

朗道的《场论》、周世勋的《量子力学》、朱洪元的《量子场论》、爱因斯坦的《狭义相对论浅说》、《相对论的意义》及矢量代数与张量分析、场论、群论等等专业著作，参看了当时理论物理专业的相关教材及科学前沿科普读物。此间，结合文革前撰写的电工基础专业论文，总共写了近三万字的心得体会，其中之一是试图将磁场中的毕—沙—拉定律与静电场中的库仑定律统归一个定律的证明；另一部分则是尔后日渐明确的“量子力学曲率解释”的萌芽思想。详细证明库仑定律和毕—沙—拉定律有统一形式的论文，记得1979年或1980年曾投寄给当时《大学物理》杂志，经多次询问，两年之后得到一回复：“此稿请编委再研究一次”。再过了两个月，《大学物理》刊登了一个告示“因为稿件太多，许多很好的稿件不能刊登，请作者谅解”。我知道我的稿件发表无望了。不过又过了两个月，1982年《大学物理》第八期上刊登了一位编委的文章，其结论与我的文章完全相同，但切入的角度不同。自此，对这篇文章问世的辗转夭折，心中有说不清的滋味。不过，后来在朋友的帮助下，在湖北省物理学会上作了交流，并发表在《武汉大学学报》当年的增刊专号上。不久，又收入我的第一部专著《运动与场》之中。我的前期研究工作就算划了一个句号。

从60年代中期到80年代中期，我的物理学哲学研究，由于时代的限制，基本上是业余时间个体作业，研究进展十分缓慢。我戏称为“地下工作”时期。

第二个阶段是20世纪80年代中期到20世纪90年代中期。在这期间，由于工作表现不错，时代将我推上了学院的中层领导岗位。工作教学之余，仍潜心从事物理学哲学研究。不过，这一时期，尽管工作忙碌，但却是我频繁从事学术交流，向专家请教，争取他们帮助、支持的重要时期。记得我前后共五次参加了中国理论物理前沿学术讨论会（此讨论会后来因会长殷鹏程去美国定居而终止）。此间我与薛晓舟、张端明、邱荣、唐超群等教授结下了友谊。1990年长沙《全国量子力学基础学术讨论会》上，我有幸结识了洪定国、柳树滋、王国文、沈惠川、殷正坤、何建鄂、关洪等老一辈或同辈专家学者，他们在我尔后的研究中分别给予了不同程度的支持与帮助。在天津南开大学理论物理研讨会上，我又结识了葛墨林、李新洲、何祚庥、孙昌璞等理论物理学家。研究科学哲学的学者成素梅也是这一时期认识的。

高层次的学术交流平台，让我有机会听取他们的指导。听说，我给何祚庥院士的印象是：在量子力学基础研究中，赵国求是坚持实在论的。我的母校，华中科技大学原校长杨叔子院士也有类似的看法。这是一个中肯的评价。在量子力学基础问题上，我确实是一个坚定的实在论者。今天的“量子力学曲率解释”就是坚持实在论的产物。1995 年世界首届华人物理学大会上，我有幸聆听了杨振宁、李政道、丁肇中、李远哲四位华人诺贝尔奖得主的报告，分组会上交流了“量子力学曲率解释”，结识了同辈学者查有梁、曹文强等。这些学术活动的参加，对我的物理学哲学研究都有重要的推动作用。

第二个时期可算作是我游历天下，结识天下英雄豪杰，向专家学习，争取他们的理解、支持与帮助的时期。

第三个阶段则要从我结识吴新忠、万小龙以及他们的导师桂起权教授开始。吴新忠思维活跃，思想敏锐，敢于突破；万小龙则以逻辑思维严谨，考虑问题深思熟虑见长，是率先研究范·弗拉森量子力学模态解释的学者；而桂起权则无论是做学问还是做人都宽厚、能容，在我看来，他还是具有战略眼光的学术旗帅。

记得 1997 年，在我的母校华中科技大学召开第八届中国自然辩证法学术年会。殷正坤教授是主要的组织者之一。受他的邀请，我参加了年会的学术讨论。在分组会上，万小龙、吴新忠在座，我的发言引起了他们的极大兴趣，吴新忠尤甚。过后，吴新忠考取了武汉大学科学哲学方向的博士生，我的学术思想通过吴新忠引起了他的导师的关注。从此，我参加了桂起权教授倡导的“科学共同体”。我的物理学哲学研究从此上了快车道。

就国内科学哲学界来说，我觉得，武汉大学科学哲学博士点十分有特色。他们的口号是“分科的科学哲学”。这意味着鼓励博士生根据原有专业背景，分别来做物理学哲学、生物学哲学或者计算机人工智能哲学等等。正好，那种不脱离科学实际内容探索科学哲学的工作方式与我不谋而合，因此，这个学术圈子非常适合于我。我常说，“谋事在人，成事在天”，成事在天就是一种机会。这就是上天赐给我的机会。此后，研究工作的顺利发展，让我终身难忘。桂起权的学术交往很广泛，他正好在一定程度上起到了我与国内科学哲学界联系的桥梁作用。面对相互对立的不同流派，我逐渐体会到，桂起权更喜

欢发掘每一派的优点。我们终于结成了研究物理学哲学的重要盟友和“战略伙伴”。

如果说第二个时期，我的主要学术活动在理论物理那一边，那么，从第三个时期开始，我的学术活动就从偏重于理论物理而走向真正的物理学哲学了。在此期间，我三次参加全国科学哲学年会，三次组织“全国物理学哲学专题讨论会”，多次专访科学哲学专家，交流、听取他们的意见。2007 年参加了第十三届国际逻辑学、方法论与科学哲学大会，报告论文引起了国际学者的关注，并收入英国出版的论文专集中。

在我们武汉物理学哲学学术圈子里，各人的学术观点远不是相互一致的，激烈的争论经常发生。按照桂起权自己的定位，在物理学哲学上他的基本立场无非是对哥本哈根学派的辩证解读，但他又是一个多元主义者，能够以开放的心态对待哥本哈根学派以外的新学派、新观点。起初这个共同体对我的接纳也就是从这一基点开始的。正好那几届人才比较集中，有 4～5 个博士生都有物理学背景，而桂起权本人也是学物理出身的，他先后三次申报成功“物理学哲学”国家课题。因此，在这个学术圈子里就有了经常地无拘束地讨论物理学哲学的良好气氛和机会。加上这个共同体的发起人在学术上的宽容态度，终于使我的原初研究有一个生长、发芽、培养、校正的机会。我深深体会到，自由争鸣是学术上任何一种新生事物成长所不可缺少的环境条件，而且依我之见，宽容精神也是任何一个权威学者应该具备的高尚品德。

量子力学曲率解释，作为一种新的解释体系，它需要自己的哲学基础。起初我对一些哲学概念的理解是简单而含糊不清的。量子力学曲率解释需要“相互作用实在”，而“相互作用实在”又要理清“自在实体”与“现象实体”的关系。这些概念最初虽由我提出，但具体论证却是在桂起权指导的博士生班子以及其他科学哲学学者的积极参与下才达到现在的清晰程度的。万小龙最先对“相互作用实在”有保留意见，我到他的住所促膝长谈也不见成功。但后来在我把相互作用原理推广、扩大到广义领域之后，经桂起权的认同，万小龙表示了理解。相互作用原理和相互作用实在才成了我们研究量子力学曲率解释的共同哲学基础。按照桂起权的总结，相互作用实在论的价值在

于，一方面肯定了主体与客体之间存在着能动的相互作用(他认为，主客截然二分是不切实际的幻想，并且有违辩证法)，另一方面，又坚持了科学实在论，从而与罗森菲尔德在《量子革命》一书中所批评的“机械唯物主义与不可救药的唯心主义”划清了界线。而这，正是我提出量子力学曲率解释的初衷。

由于曲率解释是在艰苦奋斗中成长起来的，因此长期以来是靠坚定的自信来支撑的，桂起权觉得这是我当时的生存之道。与此相关，在我的思想深处对“曲率解释”的维护难免是排他性的，在讨论之初意味着对其他解释的强烈否定。这就招来了桂起权的猛烈批评，也招来了王贵友教授的坚决抵制。我曾为此坐立不安，彻夜难眠。在近半年的思索中，我终于找到了协调的办法。“曲率解释”能包容“概率解释”！“曲率解释”正好补上了万小龙所总结的，概率解释从“数的元素”到“可感物”对“形”的缺失。“概率解释”和“曲率解释”的对应关系是：概率大的地方曲率大，概率小的地方曲率小，曲率与概率成正比例。“概率解释”的合理部分全都包容在“曲率解释”之中，而由“概率解释”所产生的悖论(paradox，或译为佯谬)，“曲率解释”则可以消除。“曲率解释”的优越性是显而易见的。有学者说“引入波粒二象性观念或概率解释是各种佯谬出现的本质”，现在看来，引入“曲率解释”或许是一个解决“各种佯谬”的可选途径。期望听到相关专家学者的指导与批评。

在讨论海森伯的测不准关系时，曲率解释则对其做了实在论解释。曲率解释认为，在原子世界，电子等微观客体虽然看不见，但我们可以通过物质波长或波尔半径进行建构。并且，在讨论原子问题时其“形”不可忽略，测不准既是测量中“形”不可忽略的产物，也是微观世界质点抽象的产物，二者是统一的。经典力学中的质点抽象原则在原子世界不适用(或不能照搬)。在微观世界进行质点抽象，由于“形”不可忽略，因此微观质点具有了新的不可确定性。万小龙把赵国求上述观点总结为“内禀非完全决定论”。这是很准确的。鉴于曲率解释对测不准关系有了新理解，而在通常情况下，科学内容与哲学解释两者很容易混淆在一起，因此，桂起权特别提醒说，有必要将不确定关系及玻恩概率解释中的科学成分与哲学成分两者剥离开来。他认为，这种剥离正是科学发展成熟的标志。

康普顿物质波与相对论相关，量子力学曲率解释讨论了这一相关性。桂起权在受到吴新忠启发后认为："把重点从德布罗意物质波转移到康普顿物质波，使人感到离自在实体又接近了一点。"这一提示，让我更加明确地感觉到了"自在实体"与"现象实体"在微观波动现象中的表现形式。而这一点我原先的理解并不深刻。

我们的武汉科学共同体的活动是频繁的，正常情况下每月我们都要集中讨论一次。争论是激烈的，针锋相对的，但态度是友好的，目的是共同的。许多共识就是在友好的争论中达成的。应该说，《相互作用实在与量子力学曲率解释》这部专著就是这些共识的基本反映。桂起权作为发起人深情地说"我喜欢这个科学共同体"。

武汉的科学共同体是一个很有生气的研究团体。桂起权在国内科学哲学界有为数众多的真诚朋友。他根据我们的研究进展，不失时机地为我引荐了许多科学哲学界的学者朋友。他希望我向那些谦虚随和的前辈和其他学者请教，参与他们的讨论，争取他们的帮助。我先后结识了董光璧、金吾伦、赵峥、曹天予、刘闯、张志林、吴彤、罗嘉昌、李醒民、胡新和、曹志平、蔡肖兵、王巍、李宏芳等就与桂起权、万小龙、吴新忠的介绍、推荐有关。我向著名学者金吾伦教授详细报告了量子力学曲率解释，蔡肖兵在座，他们的理解、支持与鼓励，所提中肯意见与指导，又让我的研究再上了一个新台阶。蔡肖兵博士、李宏芳博士(后)有加盟的意向，李宏芳已调入武汉大学，美国佛罗里达大学知名学者刘闯也曾明确表示愿意参与量子力学曲率解释研究，现在曹天予教授已同我们制订出了进一步深入研究方案，供下一步深入研究参考。武汉的科学共同体有向全国乃至海外扩展的态势，这使量子力学曲率解释研究又有了新的希望和起点。

学术成果的出版与论文的发表是判别研究成果公认程度的标志。量子力学曲率解释目前已出版专著 4 部:《运动与场》(冶金工业出版社,1994)、《物理学的新神曲——量子力学曲率解释》(武汉出版社,2002 第一版,2004 第二版)、《物理学与哲学之间——相互作用实在与量子力学曲率解释》(中国新闻联合出版社,2006)。《从相互作用实在到量子力学曲率解释》(武汉出版社，中英文合订版 2008)；专题研究论文 30 余篇，主要发表在:《科学技术哲学》(人民大学复印资料)、《自然辩证法研究》、《科学技术与辩证法》、《江汉论坛》、《科技进

步与对策》、《国际学术动态》、《社科研究》(中国香港)、《中国基础科学》、《科技导报》(中国科协)、《科学新闻》(中科院)、《科学研究月刊》(中国香港)、《武汉大学学报》、《武汉理工大学学报》、《首都师范大学学报》、《太原师范学院学报》、《武汉工程职业技术学院学报》等杂志上。其中《物理学的新神曲——量子力学曲率解释》作为由桂起权教授主持的《物理学哲学研究》课题成果，被评为国家社科基金资助课题优秀项目，并向全国推荐。2005 年，该书被武汉市政府评为“武汉市社会科学优秀成果三等奖”。2007 年，吴新忠又在国家教育部青年项目中立项，课题在进一步的深入研究中。2005～2008 年，武汉钢铁公司连续立项(量子力学基础研究：B121)支持，本书是这一研究的中期总结报告。

量子力学曲率解释研究取得了初步成绩，并不意味着“曲率解释”已经完善。相反，研究越是深入，越是感到我们的知识不足，越是觉到有更多需要完善的地方，越是渴望有更多的物理学家和哲学家参与指导，我们更需要年轻人的加盟。“路漫漫其修远兮，吾将上下而求索”。期望我们的研究在“科学共同体”的推动下，朝既定的目标奋进！

多年来，量子力学曲率解释研究一直得到了武汉钢铁公司和武汉工程职业技术学院领导的全方位支持，包括人力、物力和资金；桂起权教授通读了书稿并作了修改；一些学者朋友提出了很好的修改意见；全书英文由石茂祥教授翻译，赵国求做了配合工作；桂起权、吴新忠、雷卫华提供了相关哲学名词、科学家姓名和物理名词的标准翻译，吴新忠通读了英文全文，并提出了校译参考意见；曹天予教授通读了中、英文全书，并用英文为本书作序(石茂祥翻译为中文)；一些出版社的领导和杂志社的主编、编辑对我的研究表示了支持和关心；我的妻子和同事也为此付出了许多艰苦的劳动，在此一并表示衷心的感谢。

赵国求

2008 年 8 月改于武汉

Chapter 1
Introduction—A Realist Trial Interpretation of Quantum Mechanics

Quantum mechanics, since it was established more than half a century ago, has been regarded as one of the two pillars of the 20^{th} century physics, the other being the Theory of Relativity. And this perspective will be kept unchanged for rather a long time. The description of quantum mechanics in the microscopic world is really a striking achievement. The calculation and experiments based on quantum mechanics so amazingly conform to each other that people are firmly convinced of the correctness of quantum mechanics. Nevertheless, the great achievements of quantum mechanics can never remedy the defect quantum mechanics interpretation system and its deep-seated acute contradiction to the theory of relativity.

The so-called quantum mechanics interpretation system intends to study the physical essence of mathematical forms of quantum mechanics. As to the physical interpretation of the mathematical form of quantum mechanics, there are at least tens of the kinds, among which about 7 or 8 editions are more prevailing. And the most popular mainstream of the schools is the probability interpretation of the so-called Copenhagen School. The probability interpretation holds that the core concept of mathematical form of quantum mechanics -wave function—describes probability wave and that in essence the momentum and position of a microscopic object cannot be ascertained simultaneously, and the uncertainty relation

is the mathematical description of this uncertainty.

Nevertheless, the probability wave interpretation of M. Born greatly contradicts the experimental results of the physic reality of wave movement. In order to eliminate the contradiction in their interpretation system, Copenhagen School headed by Niels Bohr and his followers made a great deal of improvement and progress in this respect, but simultaneously added some unusual philosophical ideas and arguments. In Copenhagen probability interpretation, mathematics, physics and philosophical ideas were mixed together, forming a mysterious quantum fog. For decades, even such greatest physicians as Albert Einstein were involved into the quantum fog. Many scientists, such as Louis de Broglie, Erwin Schrodinger, David Bohm, and Blokhintzev, once tried to replace Copenhagen interpretation with their own but they did not establish themselves as the mainstream schools, for they could not solved the problems in quantum measurement, EPR imaginary experiment and quantum probability. In a long run, the physics essence of mathematical form in quantum mechanics still needs further research and probe. The curvature interpretation of quantum mechanics, one of the many further interpretations of quantum mechanics, is a new quantum mechanics interpretation system being studied in China. The curvature interpretation of quantum mechanics extracts a curvature factor from amplitude of wave function, for it is believed that wave function will describe the laws of the change of the "image" constructed by the wave length of the matter wave for microscopic object through experimental appearance. On each space-time point, a curvature responding to the "image" of the microscopic object is changing. When the "image" is big, the probability is small to find point particle in the "image", and vice versa. Thus, probability and "image" (curvature) is changeable. Curvature interpretation recognizes the validity of inner probability interpretation, and further points out that: wave function is curvature wave, the bending

degree expressed by curvature represents corpuscular property, the change of the bending degree expressed by curvature shows undulatory property. The curvature interpretation of quantum mechanics possesses logic consistency in relation to philosophy, physics, experimental appearance, and mathematics and interpretation system. Many paradoxes caused by Copenhagen probability interpretation will disappear in the curvature interpretation of quantum mechanics, and the curvature interpretation of quantum mechanics may absorb the reasonable part of probability interpretation in its own theory.

1.1 Marx Born's Probability Interpretation and Probability Geometrization

All seriously considered interpretations of quantum mechanics started from the interpretation of M. Born probability. From M. Born's rule, the probability of measuring results is to be pre-calculated from the standard theory of quantum mechanics. M. Born's rule is so successful in the interpretation of quantum mechanic state that it itself is regarded as part of the theory. However, the recognition of M. Born's interpretation of probability does not mean that there appears a conformal understanding of the physical denotation and its philosophical denotation of quantum probability in the basic study of quantum mechanics. As a matter of fact, it is from the different interpretations of M. Born's probability that diversity of the interpretation of quantum mechanics occurs. Up to the present time, the interpretation of quantum mechanics have developed for nearly 80 years, the survivals of which are Bohm's causal theory, decoherence interpretation, interpretation of relative state, modal interpretation, Copenhagen-Von Neuman interpretation and lowest-limit statistical interpretation. They may be ranked according to the explanative conditions from more requirements to the lesser

and its explanative power in the order from the strong to the weak, on the basis of which many feature issues of quantum mechanics theories and natures of the quantum phenomena have been deeply discussed and understood, and these theories respectively revealed some unnoticed metaphysical foundations of quantum reality from certain angles. Among the explanative theories of quantum mechanics, however, one tendency—geometrization of the quantum probability—is worth noticing.

Rene Thom, French mathematician and the founder of catastrophe theory once regarded wave function as Morphogenesis. In his *Structural Stability and Form Development*, published in 1972 (its Chinese version was published by Sichuan Educational Press in August, 1992), Rene Thom, after criticizing quantum mechanics point particle model, put forward his viewpoint of regarding wave function φ as the hypersurfacial form of topological type changing at certain frequency. He also made geometrical interpretations on quantum mechanics wave function. [1]

Van Frassen introduced his simplified model of geometric probability in his book *Quantum Mechanics: On Empiricist's view*. Van Frassen verified that the geometric conversion of the probability could indicate quantum conditional probability of Hilbert space in any dimension.

Wuhan Scientific Community, advocated by Mr. Gui Qiquan, comes into a common opinion about the geometrization methods of quantum mechanics, while discussing rationality of the curvature interpretation of quantum mechanics. After carefully observing the methodology of Pythagoras's theoretical construction, Mr. Wan Xiaolong believes that there are three steps and four key points in Pythagoras's theory-constructing methodology[2]: ①From mathematical elements to figures (a～b); ②From figures to forms (b～c); ③From forms to sensate objects (c～d).

Provided that relations are added to each main point in Pythag-

oras methodology, for example, altering number elements to the relation of number elements, the interpretation of wave function can also refer to the revised Pythagoras methodology: from relation of number elements to relations between numbers, and then from the relation of forms to the relation of sensate object. Quantum mechanics interpretation theory is a case in point, in which the probability interpretation of wave function can be regarded as the interpretation of number relation of wave function—the relation between number elements.

(a)	(b)	(c)	(d)
Relation of number elements	Number relation	Form relation	sensate object
wave particle duality	Matrix mechanics, Wave mechanics	Von Neumann abstract space	Observable value
wave function	M. Born probability interpretation	?	Observable reality

From the above chart, it is obvious that, in the interpretation of wave function, a relative step(c) is needed, that is, "form relation", without which, (b) directly jumps to (d). Although no problem is left in the experience prediction, many puzzles from the interpretation appear, which indicates that probability interpretation based on wave function measurements is not complete. As a result, if the physics meanings of wave function should be clarified and realist (not only observable value) interpretation is given to micro particles in measuring result, re-interpretation of forms (geometric relations of space) should be given to the interpretation of wave function probability (quantity relations) .

Prior to Rene Thom, Zhao Guoqiu independently put forward quantum mechanics curvature interpretation—another geometriza-

tion hypothesis of wave function. His primary achievements are comprehensively defining curvature from the concepts of uncertainty rule, matter wave wavelength and Bohr radius of hydrogen atom, directly extracts curvature factors [3] from the amplititude of various wave functions, and verifying that wave function is curvature wave. His methodology, taking the construction of microscopic object "image" as its goal, is a geometrizational direction and, although different from the methodologies of Rene Thom and Van Frassen, can best express physical reality described by quantum mechanics.

1.2 Curvature Interpretation of Quantum Mechanics

What is curvature interpretation of quantum mechanics? What is the basic thought of curvature interpretation?

The basic thought of curvature interpretation of quantum mechanics can be illustrated as follows: it does not acknowledge microscopic object as mass point, and mass point abstract rule in classical mechanics cannot be applied to atomic world (or copied). To abstract microscopic objects, as electrons in atoms, mass points are virtual and waves are real. In existing quantum mechanics, equivalent structure, which mass point corresponds to and which possesses phenomenological meaning, is embodied in the form of wave function(curvature wave), in the results of the theory.

In curvature interpretation of quantum mechanics, it is believed that in atomic world, the "image" of microscopic object, although invisible, can be constructed through experimental appearance, theories and logical reasoning, and the constructed "forms" cannot be neglected in the discussion of atomic issues. In quantum mechanics, wave function describes the law of change of "surface curvature" in microscopic object itself. Wave function is curvature wave. The curved degree of curvature indicates corpuscular proper-

ty while curvature changes show undulatory property, which is the important revision of mass-point model.

The system of curvature interpretation of quantum mechanics can be established on the three strata—electronic "transformation from light to image", "quantitative construction of 'image'" and "transformation of image into point".

1.2.1 Transformation from light to image

In macrocosm, the experiential objects are all visible with naked eyes, and the "image" of an object is constructed by the biological instrument—human eye-brain system, through observation information (continuous irradiance), at most with the extension function of an instrument. It may be said that, the "substance-in-itself" of physical reality passes through the continuous effect of light, the "object" directly perceived by human eye-brain system is the transformation of the "image" of the object in human brain by light, which is referred to as microscopic "light-image" conversion. The "image" of macro object is generally considered invariable by experience, while in microscopic world, especially in atoms, microscopic objects like electrons cannot be seen directly, even with the help of "the extension of instruments". However, electronic "substance-in-itself" —"reality" —and its "image" in the atoms—"substance of appearance" —can only be identified through atomic irradiance. Atomic irradiance is the product of electron transition, but only the frequency and intensity of light emitted or absorbed are known when an electron transits, which is discontinuous spectral line. Discontinuous light cannot build a successive electronic image in human brains. An atom was once imagined as raisin, with electrons fitted in it like sand. And then, electrons were thought of as smooth beads of stable shape rotating around atomic nucleus in the way that planets rotate around the sun. Such imaginations are proved wrong by experiments. Quantum mechanics, introducing

wave function, successfully describes the undulatory property of microscopic object, which conforms to the experiments. Nevertheless, quantum mechanics abstracts an electron (of unknown "image") to a mass point, which is believed to be the main reason why the present Copenhagen interpretation of quantum mechanics has brought about so many cognition problems. [4]

It appears, a solution to the problem is to construct a proper "image" for the electrons in atom. An electron produces discontinuous spectral line in energy level transition, but human eye-brain system is unable to identify its "image" directly. And we must identify electronic image through light! So, we have to resort to the frequency and intensity of atomic irradiance to construct it through our experience, knowledge, theories and logic reasoning. Provided that such construction could be reduced to appearance and agree with our observation, it should be the physical reality described by the theory.

To construct the "image" of electron in atom, we make an analogy between bending extent of curved surface and variety of radiant (or light-reflecting) intensity, and their corresponding relation is built as follows: ①Corresponding to plane surface, irradiance (intensity) is zero, and curvature is zero; ②Corresponding to curved surface, irradiance is weak, and curvature is less bent; ③Corresponding to curved surface, irradiance is strong, and curvature is more bent. "Curvature model" can be used to replace "mass-point model" in the description of microscopic object.

In this way, irradiant intensity of the electron transition in atom has a relation with geometrical "image" at certain energy grade of electronic "substance of appearance" to be constructed. Owing to the different irradiant intensity of different energy grade in atom, its "curvature" connected with the electron is changeable. Thus, the electronic "image" in atom is also changeable. Electrons continuously transit in atom and its "image" is changeable in the

movement, which is different from macro phenomenon. Macro "light-image conversion" varies greatly from micro "light-image conversion". But the constructed micro "substance of appearance" can be changed to observable macro "phenomenon" or substance of appearance through quantum measurement.

The above model is called curvature model. "Curvature model", in fact, is a "field theory" model, a "painted mass point", which has better constructed a traceable and clear "corporeal" subject of study.

1.2.2 Quantitative Construction of Electronic "image" in Atom.

1.2.2.1 Inspiration of Hydrogen Atom

Radial wave function of hydrogen atom is usually written as:[2]

$$R(r) = \alpha B_0 e^{-\rho/2} \rho^l \angle_{n+l}^{2l+1}(\rho)$$

$\alpha = 2/na_0 \quad \rho = \alpha r = 2r/na_0$

$$B_0 = -b \frac{(2l+1)!(n-l-1)!}{[(n+l)!]^2} \tag{1.1}$$

The above formula can be changed into the following through calculation:

$$\begin{aligned} R(r) &= R_n 2B_0 e^{-R_n r} \cdot (2R_n r)^l \angle_{n+l}^{2l+1}(2R_n r) \\ &= R_n \cdot G(r) \end{aligned} \tag{1.2}$$

In the equation $R_n = 1/na_0$, a_0 is Bohr radius, and n is quantum number on the energy level, while R_n possesses curvature dimension. R_n is the amplitude of the wave (R_n^2 is electronic "surface curvature"), and wave function of hydrogen atom can be regarded as curvature wave.

1.2.2.2 In hydrogen atom, the construction of electronic "image" and the relation of "image" and curvature R_n

In hydrogen atom, Louis de Broglie matter wave wavelength of electron on energy level n.

$$\lambdabar_n = \hbar/p_n = na_0 \tag{1.3}$$

$\lambdabar_n$ can be regarded as phase circle radius, with λ_n as circumference, R_n is circular curvature, which is R_n in formula (1.2). So, each energy level n of hydrogen atom defines the curvature R_n (also called reference curvature or base curvature) corresponding to the electron pair via Louis de Broglie matter wave wavelength. $r_n = na_0$ (Radius of reference curvature) reveals electron's basic image on each energy level of hydrogen atom through the frequency and intensity of light. Hydrogen atom wave function is curvature wave with R_n as amplitude, which provides the "structure" information of the electrons. $R_n \cdot G(r)$, or $R_n \cdot G(x)$, simplified forms of wave function indicates that a curvature corresponds to electron pair at each space-time point; in experimental appearance, it indicates the correspondence of irradiant intensity with the frequency of the electron transition (or scatterance). Electron motion pattern is changeable at different energy levels in hydrogen atom. With the help of R_n or $R_n \cdot G(r)$ (or $R_n \cdot G(x)$), electron's "pattern structure" can be analyzed and perceived.

In any other wave function of matter wave, from its amplitude, a radius of curvature r_n and curvature R_n defined by matter wavelength λ_n can be separated. The above analysis of hydrogen atom is of universal significance. (see appendix 3)

1.2.3 Image-Point Conversion

In atom, we use Louis de Broglie matter wavelength λ_n on each energy level to construct a basic "image" for electrons, expressed by curvature R_n. We will prove that, in discussing atoms, the "image" constructed for electrons in atom cannot be overlooked, or it does not accord with the abstract rule of macroscopic mass point; the mass point is virtual if we rashly abstract mass point. Any point exists in the "image", and the wave is real although there is no track of movement. Obviously, the smaller the "image" of the

electrons, the greater the curvature R_n is, and the more bent the probability to locate point particles in the "image"; the bigger the "image" of the electrons, the less bent the curvature R_n is, and the smaller the probability to locate point particles in the "image". The standard "image" of electron at each energy level is different and the probability of its appearance is different. The curvature is changing at each space-time point, so is the probability of its appearance. Probability and curvature is interchangeable.

That is what we mean "image-point conversion".

The "image-point conversion" in the curvature interpretation of quantum mechanics acknowledges the validity of the interpretation of intrinsic probability, which may hush up all the contradictions of probability interpretation and the logical part of the latter is absorbed into it. Comparing curvature interpretation with probability interpretation, physical reality described by theory is more penetrating and complete in cognition: Essentially, wave function is curvature wave, curvature volume indicates corpuscular property, and curvature variety indicates undulatory property, so curvature and probability is interchangeable. Undulatory property and corpuscular property co-exist in the same model and wave particle duality is harmonious with microscopic object itself. The curvature interpretation of quantum mechanics is coherent with philosophy, physics, experimental phenomena, mathematics and logics of interpretation system.

1.2.4 Uncertainty of "image" and Location of Electron

According to Werner Karl Heisenberg's uncertainty rule, at each energy level in atom, the uncertain measurement Δp_n of electron's momentum and Δx_n of the location will satisfy the following formula:

$$\Delta p_n \cdot \Delta x_n = \hbar \tag{1.4}$$

In discussing atomic electron, the electron's momentum is generally

regarded as electron's momentum uncertain measurement, so:

$$\Delta p_n = p_n \tag{1.5}$$

Together with formula(1.3), we get (radius of phase circle)

$$r_n = \lambda_n = \Delta x_n \tag{1.6}$$

Known from uncertainty rule, the physical sense of Δx_n is the uncertain location of point electron, the measurement of which exactly equals the "radius of curvature" of electron's "image" constructed. The uncertain measurement just emphasizes the importance of the electron's "image" in atom. (Compared with atom's "image" $r_n = n^2 a_0$) mass point abstract rule does not suit or copy this basic thought. Thus, uncertainty principle possesses realist background, which reflects an internal relation between interior space and realistic space.

It must be pointed out that what we mean about electron's "image" is the construction of an optical phenomenon, which is not equal to "point electrons of substance structure" in classical mechanics content. On the contrary, it shifts the mechanical property "mass point" bears in classical mechanics, and as a "structure wave", there is no cognitive problem in calculating electronic "self-energy". The constructed "image" is, in fact, "equivalent structure field corresponding to mass point", and all the substantial properties of mass point in classical mechanics(including quantum mechanics)are reflected in the results of field theory. As a result, all the cognitive contradiction substantial mass point reveals in quantum mechanics is to be eliminated here.

1.3 Philosophic Foundation for Reality of Curvature Interpretation in Quantum Mechanics

1.3.1 Interactive Rule and Interactive Realism

General interactive rule refers to the universal relation among

substances.

Special interactive rule points out: in natural world, the "image" and "state" of all matters in space-time are formed through interaction of substances; including four basic interactions (gravitation, electromagnetic force, strong interaction force, weak interaction force) and observational signal functions the humans use to observe the world. Special interactive rule is the philosophical foundation on which quantum mechanics curvature interpretation is established.

From special interactive rule two deductions are acquired:

Deduction 1: without interaction, "substantial reality" cannot form observable space-time image.

Deduction 2: where space-time diversifies is where substance is and where field source is.

Applying special interactive rule and its deduction, we obtain two basic concepts, "substance-in-itself" and "substance of appearance". "Substance-in-itself (reality)" is objective existence, away from human subjective consciousness and it is abstract and non-factual cognized; "Substance of appearance", which is concrete and cognized, is formed by "substance-in-itself" (reality) through four basic interactions (gravitation, electromagnetic force, strong interaction force, weak interaction force) and by means of observational signals functioning on human body—the biological instrument—and the extension of "man-made instrument". The humans establish their knowledge of the natural world in three basic ways: ① the direct establishment from the experience of their senses; ② the establishment through their senses and the extension of the senses; ③ the indirect establishment through appearance, knowledge, theories and the relative logical structures. Different as their cognitive levels are, they are the construction of reality; nevertheless, the first two are of experience or experience plus rational level, while the latter is rational level. Space-time concept, synthesized and

abstracted from "substance-in-itself (reality)" and "substance of appearance", reveals the extensiveness of substance and continuity of motion process. Space-time possesses either unchangeable property or changeable property, which depends on different levels of human cognition. Newtonian mechanics, relativity mechanics and quantum mechanics are all established on different space-time basis, and it indicates that the humans have different levels of rational cognitions.

Interaction is a universal connective form of substances and appearance. "Substance is the cause of itself." (Benedictus Spinoza) "Interaction is the real and ultimate cause" (G. W. F. Hegel, Friedrich Engels). [5] It is evident that substances exist in interconnection and interaction. Based on general and special interactive rules, we put forward the theory of interactive reality or the theory of interactive constructive reality, and believe that it is one of the prevailing editions of structural reality.

1.3.2 Distinguishing Micro-Function Mechanism and Macro-Function Mechanism

Without interaction, "substantial noumenon" cannot form observable space-time image. It is obvious that interactions in the natural world are common bases that produce macro and micro natural phenomena. However, owing to the essential difference of the functional mechanics of microscopic and macroscopic worlds, there is essential difference in the production mechanism of macro phenomena and micro appearance. Microscopic world possesses quantum properties; its energy is discontinuous, but its interaction is interrupted ($h \neq 0$). According to special interaction rule, the "image" of an object is revealed through interaction, and then in microscopic world, "image" and "state" provided by interaction is discontinuous, interrupted and scattered between two energy levels, thus forming independent interference wave sources. The ca-

tastrophe of "image" demonstrates that, when "image" suddenly changes, its process between energy levels is unknown. It is understandable that, in mathematics, "up-image" and "lower-image" is equal to zero in each other's projections, a necessary condition in establishing orthogonal system in mathematics. Physical model and the mathematical form of linear function are then coordinated and unified. Here, "upper-image" and "lower-image" become coordinate axes of orthogonal system. The catastrophe properties is covered or "folded" by origin of coordinates, (called space-time blindness). In quantum mechanics, Hilbert space gains authentic physical sense. Meanwhile, quantum mechanics requires that "upper-image" and "lower-image" be linear, continuous and single-valued periodic function, which illustrates that each energy level itself presets continuous effect mechanics and, with it, connects with the macroscopic world. Because coordinate axes can describe the features of "image's" change, wave function essentially describes the law of change of broad distribution patterns of microscopic objects. However, human eye-brain system cannot identify such "imageless" objects.

In macroscopic world (or classical mechanics), interaction (gravity and electromagnetic force) is regarded as continuous, and the change of energy is continuous, that is, quantum of action h=0. Catastrophe does not exist in human cognition of "image" provided by interaction in macroscopic world, with no concept of "up- and lower-energy level discontinuity. The change of objective "image" is also continuous; the change of the state formed by the difference of energy amount does not construct "physical" orthogonality. "Image" is of local property, and it is not scattered everywhere in space. That is the physical mechanism formed by macro classical particle locality "image" and separated from background space-time. The human eye-brain system is able to identify such "visible" objects.

In mathematics, between discontinuous superposition mark $\sum$ *and continuous superposition integral mark* $\int$, the transition $\sum \rightarrow \int$ is realized by means of infinitesimal analytical tools, but in physics, they become two things of different properties. It embodies a leap forward of quantitative change to qualitative change in physics when discontinuous effect transits to continuous effect, which reveals that the micro essential "catastrophe" transits to macro phenomenal "discontinuity". Erwin Schrödinger equation describes the change of the condition of the two different properties.

1.3.3 Distinguishing essential differences of microscopic mass point and macroscopic mass point

Owing to the essential difference of function mechanics, the attributes of macroscopic mass point and microscopic mass point are also fundamentally different.

In macro classical mechanics, so-called mass point indicates that in the discussion of problems, the size of objective "image" can be neglected and that an object is simplified as a "mass point". When force is exerted on the mass point, the momentum, energy, location and time of the object are all given to the mass point. Thus, mass point in classical mechanics has the properties of the substance, while the background space of the mass point motion is virtual. The description of objective state in space-time movement automatically turns to the description of mass point motion track in different space-time frames, while interactive continuity guarantees the continuity of the motion tracks, and ensures mathematical application basis of differential and integral equations. [6] Energy, momentum, location and time of the mass point are definite, and the coincidence of mass point and background at geometrical point ensures mass point (object) motion track definite. Experiment also well accurate prevision of mathematical methods corresponds to.

In microscopic world, or deep in the atoms, macroscopic mass point abstract rule cannot be used (or copied). The energy level radius in atoms $r_n{}' = n^2 a_0$, while corresponding to electron's standard curvature radius(phase circle radius) at energy level $r_n = \lambda_n = na_0$, a_0 is Bohr radius, both are in ratio $1/n$. $n = 1$, and atom is "as big as" electron. Even if $n = 10$, "atom" is only ten times bigger than "electron", and such atom has not been found now. Considering electron's motion in atom, abstracting electrons to mass point may not be inconsistent with the macro classical mechanics abstract rules. When electronic "image" cannot be neglected, location uncertainty is to occur. Analysis shows that, the closer the electron is to atomic nucleus, the less the "image" is to be neglected, the stronger the electronic undulatory property is; the farther away the electron is from atomic nucleus, the more the "image" is to be neglected and the weaker the undulatory property is. When $n = \infty$, $1/n = 0$, and when electron is compared with atom, its "image" can be neglected. Electrons can be abstracted to macroscopic mass point, showing complete corpuscular property. Clearly, electrons outside the atoms can be described by classical electron theory.

Since the electronic "image" in the depth of atom cannot be neglected in the discussion of atom, mass point has different property from macroscopic mass point if macroscopic classical mechanics mass point abstract methods are applied in the discussion of the atom issues. Mass point is virtual, but wave is real with physical reality. To abstract the electrons in atom, the "nominal particle" must be in the scope of the "image", and if the "image" is different, the probability to find virtual particle in it is different (which is named as "image-point conversion"). The probability gets bigger as the "image" gets smaller, while the probability gets smaller as the "image" gets bigger. Thus, there is a direct proportion among the irradiant intensity of the energy level, the electronic "surface" standard curvature of different energy level structure, and the

probability of the appearance of microscopic mass point at different energy levels when electrons are abstracted to mass point. So, according to the above mode of thinking, we connect Werner Karl Heisenberg's matrix mechanics, Erwin Schrödinger's wave mechanics (curvature wave) and Copenhagen's probability interpretation on the basis of physical mechanism, while in Copenhagen interpretation, probability wave property was obtained in the measurement of microscopic object and mass point abstract. According to our reanalysis and comprehension, probability interpretation and the uncertainty rule of Werner Karl Heisenberg have the realist background, which happens to verify Paul A. M. Dirac's prediction,[7] that quantum mechanics still belongs to determinism. This comprehension from Mr. Guoqiu Zhao is named as intrinsic non-complete determinism by Mr. Xiaolong Wan, so as to be distinguished from present determinism, non-determinism and non-complete determinism in current philosophy of quantum mechanics.

In the past, non-determinist physicists and determinist physicists believed the existence of substantial electron, but none of them could compellingly convince people how this "electronic substance" (which is either particle or wave) existed, which later provided evidence and excuse for counter-realists. In their opinion, they would rather cast away that disagreeable "electronic substance" and regard certain "appearance" in the microscopic world as abstract relation constructed from experience. So doing, the logic chain of reality is broken: "electronic substance" disappeared and "appearance" and "relation" remained. In this way, the pains of "substantial electron" pursuit disappeared—from which we seem to have achieved our spiritual freedom, but who knows that finally the humans may have problems considering their own existence if the substances are virtualized and the relations are emphasized—from which the humans would have more problems in their comprehension. The study of quantum mechanics curvature interpretation

illustrates that the methods of "breaking logic relations" is only a way out of no way. As a matter of fact, the humans can take effective measures to connect the broken logic chain, and quantum mechanics curvature interpretation is a trial solution, which belongs to realism. It is the radical difference between quantum mechanics curvature interpretation and the theories of anti-reality and relation reality to strengthen relation's "twists" and to make relations virtualized. [8]

Substantial noumenon is objective existence away from human subjective consciousness. Static energy m_0c^2 in theory of relativity, Compton momentum m_0c , and Compton wavelength $\lambda_0 (= h/m_0c)$ of quantum mechanics are all invariants when objects' corresponding coordinate system is static, which is beyond the human perception and similar to the property of what we called "substance-in-itself" or "reality". The changes in energy, momentum variation, and difference of wavelength are related with the dominant position of the relevant people, and they are of constructive property. While $r = \lambdabar = \hbar/mc$ (m as motional mass), $m = m_0/\sqrt{1-v^2/c^2}$ are the properties revealed from "substance of appearance" under the condition of theory of relativity and in continuous effect. [9] "Noumenon", "substance of appearance" and "appearance" have important inner relations.

1.3.4 Distinguishing Essential Difference between Quantum Probability and Classical Probability

In Newtonian mechanics, substance is abstracted to mass point, and space-time is absolute when image's size and change are neglected; from relativistic mechanics, feasible studies may prove the influence of the changes of the observed image caused by object's movement on space-time; when changing from Lorentz transformation to background space-time, [10] object becomes mass point but space-time is changeable; in quantum mechanics, after the changes

of the observed image caused by object's movement has gone through $dv = |\psi|^2 d\tau$, integrated space possesses curvature property, and it is real and fluctuated, which can be described by Hilbert space in mathematics.

In classical probability, "mass point" abstracted from object possesses the property of the object. It follows Blaise Pascal superposition rule: after object passes two-slit, its picture is single-peaked, and mathematic equation of probability is $p = |\psi_1|^2 + |\psi_2|^2$; abstracted from object in quantum probability, mass point is virtual, with uncertainty. Curvature wave is real that reflects shape changes of microscopic object. After micro object passes two-slit, its picture on the screen is multi-peaked, not following Blaise Pascal superposition rule, and its mathematical equation is $p = |\psi_1|^2 + |\psi_2|^2 +$ interfering item. Which slit of two-slit virtual mass point passes is of no significance because, in macro classical mechanics, the property given to mass point is also given to curvature wave. After micro object passes two-slit, its wave function possesses dual properties: curvature can be transformed into probability and probability property is contained in curvature wave. On the screen, the probability of the locating point of point particle is determined by the probability property of wave function; the transformation of virtual point particle to real point particle is determined by space property of wave function. In quantum measurement, the interference of interaction between instrument and tested system—macro continuous effect—is the important condition to eliminate independent interference wave sources and transform "spreading wave state" to "local particle state". Obviously, there is a certain process in the transformation, which cannot change suddenly, thus there is connection between wave function before measurement and that after measurement. It is the interference of continuous effect of macro instrument that helps to form "the self-entanglement" of wave function, or "self-entangled state". The en-

tanglement of wave function is that of "image", reflecting how wave function before measurement is transformed into wave function after measurement. And this process is decoherence process. In the new environment, if "image" can be ignored, "virtual mass point" becomes real. Quantum measurement has completed the transformation by reducing microscopic object to follow classical probability from following quantum probability. To express it more vivid, "when God plays a dice", he may have the obverse side, or reverse side, or obverse plus reverse side; while the humans can only have obverse or reverse side. Quantum measurement completes the conversion from "God" to "man".

Because the curvature change of curved surface and atomic irradiant intensity are linked together, where the curvature is more bent the irradiance is strong and where the curvature is less bent the irradiance is weak. The intensity of light and the "visible degree" of object is related, thus we can relate probability with the visibility of the observed object (the construction of visual experience and "image"). The frequency of electron's appearance is high where the visibility is high, or vice versa. So it is called visibility interpretation of probability , an important feature of quantum probability in atomic world, which indicates the probability (or observables) to find micro-particles somewhere in atom (or screen) or the change of optical property produced there by microscopic object. The property of continuous change of visibility, as is mentioned above, decides the continuous single value of the change of electronic "image" at each independent energy level. Probability frequency interpretation is the definition of macro-classical probability, and visibility interpretation has overcome the definition confusion of macro and micro-probability.

Erwin Schrödinger equation describes the wave equation of the changes of two kinds of "images" of microscopic objects different in quality in Newton's space time theory. After the normalization of

atomic wave function, Hilbert space on eigenstate-constructed base is undulatory, with substantial property; mass point is virtual and erratic. Such mass point, without the property of substantial track, is "substantial mass point ghost". Two-slit interference is realized by Hilbent space undulatory property, so which slit virtual electron "ghost" will pass is of no importance any more. Two-slit interference experiment is fully and perfectly explained.

To sum up, when Erwin Schrödinger wave equation describes microscopic world, it is not describing mass point movement track equation of microscopic objective, but the "image-curvature" change equation constructed for microscopic object—wave equation of curvature change. It is not that microscopic object itself has no track, but that we cannot construct its track movement through experiment. What we construct through experiment is our cognition of the "image" changes, which can be converted to the probability of the "electronic" appearance at different space-time points.

1.3.5 Revealing the Different Properties of Macro and Micro Space Time and the Difference between Described Objects and Describing Approaches

Now, we have reasons to distinguish Newton's space-time theory, theory of relativistic space-time and theory of quantum mechanics space-time.

Newton's space-time: Its remarkable feature is the background separation of objects and space-time; space-time is absolutely invariant vacant space. The objective "image", established by human senses, is regarded as invariant and there is no influence on their background. In the discussed issues, if objective "image" is neglected, the object can be abstracted to mass point, which coincides with the geometrical point of background space-time, possessing all the objective properties; momentum, energy, location and time are

determined. The description of objective movement states is the description of mass point motion tracks. In Newton's space-time, quantum of action $h=0$, light speed $c=\infty$ and mass point can be regarded as the physical reality of theoretical description.

Theory of relativistic space-time: The essence of theory of relativity is that it has discovered the non-separation of space-time features and objective movement. However, the "image" of substance itself can also be seen as invariant when the influence of "image variation" (its length shrinks along moving direction—Hendrik Anton Lorentz) produced by different objective movement on space-time is converted to space-time variation of coordinate system connected with moving objects. Human understanding of space-time has gone through new and profound changes. In the discussed issues, if "image" can be neglected, objects can be abstracted to mass point, and theory of relativistic mechanics is still mass point mechanics. In special theory of relativity, mass point has substantial property, but space-time has relations with objective motion states, which is the essence of space-time concept. In theory of relativistic mechanics, the description of objective motion states is also the description of mass point motion tracks. Nevertheless, with the coordinate system of different motion states, space-time record is different.

In special theory of relativistic space-time, we can also believe that quantum of action $h=0$, light speed $v=c$, theoretic physical reality is still mass point. General theory of relativity has great changes: although $h=0$, $v=c$, space-time is curved, and light moves in curved line. Besides mass point, theoretic physical reality also has "field".

Quantum mechanics space-time: Generally, the human beings are accustomed to using macroscopic space-time to understand the phenomenon of microscopic world, and they presume that the "image" of micro object is unchangeable and that, like macroscopic ob-

jects, it can be separated from background space and be abstracted to mass point. That is the basic reason that quantum mechanics produces too many cognitive problems. [11] The "image" of such microscopic objects as electrons cannot be constructed directly from human senses, but indirectly from atomic irradiant phenomenon and matter wave wavelength. Studies show that in discussing atomic phenomena, when we abstract microscopic object to mass point, the influence of the microscopic objective "image" on the problems concerned can be neglected. Then, on one hand, objects cannot locally separate from background space-time; on the other hand, if they separate, only an "uncertain virtual mass point" and variation property linked with microscopic object is to be obtained. In microscopic world, space-time is real with undulatory property; mass point is virtual with uncertain property. The most essential feature of quantum mechanics is $h \neq 0$, its function discontinuous. Light property of quantum mechanics can be classified into three types: ①function on quantum $h \neq 0$, light speed $v = \infty$, space-time is leveled and light moves straight. ②function on quantum $h \neq 0$, light speed $v = c$, space-time is leveled and light moves straight. ③function on quantum $h \neq 0$, light speed $v = c$, but space-time is curved and light moves on curvilinear route. Although expressing form of quantum theory on different levels of cognition is different, curvature wave, virtual mass point is physical reality described by quantum mechanics in atomic world. Wave function is either objective or real.

Through normalization, quantum mechanics can also transfer the image-changing property of the microscopic object into the space property of Hilbert space.

Given $$c = 1/V, dV = |\psi|^2 d\tau \tag{1.7}$$

Normalization coefficient $c = 1/V$ indicates that normalization is for volume ratio of V space. Formula (1.7) is the transformation of V space(quantum mechanics Hilbert space—Von Neumann configura-

tion space) and Isaac Newton's space (τ); V , with energy grade concept, is the reformation of Isaac Newton space's vacant property, with real physical connotation, called structure space, which varies with the change of curvature R_n . In V , when Lorentz transformation is applied to free variables (x, y, z, t), Erwin Schrödinger equation is transited to Paul A. M. Dirac equation. Vacuum property in quantum field theory should be V space property.

In quantum mechanics, the transition of quantum state is that of catastrophe, together with super velocity of light in Newtonian mechanics ($v=\infty$, h=0); there is light speed limit in special theory of relativity($v=c$, h=0), which are the logic convention made for observed signals according to experimental appearance when humans describe natural phenomena in their cognition of the world. Hence one can see that, in their pursuit of a unified prospect of the world, what the humans can do is to make an organic and reasonable connection of different cognition levels (to find out the logic universal joint in different levels), but not rashly attribute to different cognition levels of function mechanism to certain single level.

In brief, for half a century or so, great achievements have been made in the description of quantum mechanic in microscopic world; however, there still exist the knotty problems of interpretation caused by quantum mechanics and the deep-seated contradictions of the theory of relativity (determinism or non-determinism and locality or non-locality). The curvature interpretation completely agree with the reasonable part of probability interpretation, but it further believes that the difficulties of quantum mechanics in solving problems lies in its disregards of microscopic object, such as the construction of electronic microscopic object and irrational application of macroscopic mass point abstract rule in microscopic world. Although there are still much to be gained and studied, curvature interpretation may bring important enlightenment to the development of quantum mechanics interpretation, for, starting from

probability geometrization, it attempts to reveal the common features of Newtonian mechanics, theory of relativity and the idealized methodology of physical model of quantum mechanics.

Reference

[1] Rene Thom. Mathematical Models of Morphogenesis [M]. Translated by Zhou Zhongliang. Shanghai: Shanghai Translation Publishing House, 1989:215-280.

[2][3] Zhao Guoqiu, Gui Qiquan. New Divine Comedy of Physics[M]. Wuhan Publishing House, 2004:170,174,279.

[4] Shoichi Sakata. Shoichi Sakata Collected Works of Science & Philosophy [M]. Translated by An Du. Beijing: Knowledge Publishing House, 1987:140.

[5] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000:215.

[6] Zhao Guoqiu. Essential Difference and Mechanism of Action of Classical Mechanics and Quantum Mechanics and Issues of Quantum Measurement//Science &Technology Review [J]. 2003(2).

[7] Dirac, Paul Adrie Maurice. Direction of Physics [M]. Translated by Zhang Yizong. Beijing: Science Press, 1981:9.

[8] Zhao Guoqiu. Interaction Rule and Logic Basis of its Epistemology//International Academic Developments [J]. 2001(5).

[9] Zhao Guoqiu. Compton Substance Wave and Curvature Interpretation of Quantum Mechanics//WISCO University Journal [J]. 2000(1).

[10] Zhao Guoqiu. Curvature Interpretation of Quantum Mechanics//Advance of Science and Technology and Strategy [J]. 2000(11)

[11] Zhao Guoqiu. Classical Probability and Quantum Probability// Science &Technology Review [J]. 2003(4).

第 一 章
导论——量子力学解释的一种实在论尝试

量子力学自创立至今,已有大半个世纪的时间。几十年来,人们把量子力学和相对论看作是 20 世纪物理学的两大台柱,今后,恐怕还会有很长一段时间不会改变这一看法。量子力学对微观世界的描述确实取得了惊人的成就,利用量子力学所做的计算与实验惊人地符合,常使人们对量子力学的正确性深信不疑。然而,量子力学的巨大成就,绝对掩盖不了量子力学诠释体系的不足以及与相对论深层次的尖锐矛盾。

所谓量子力学诠释问题,指的是量子力学数学形式的物理实质究竟是什么。关于量子力学数学形式的物理诠释,见诸于经传的至少有十数种,比较流行的也有七八种,而最为流行的主流学派是所谓哥本哈根学派的概率解释。概率解释认为量子力学数学形式的核心概念——波函数所描述的是概率波。微观客体的动量和位置本质上是不能同时确定的,测不准(或不确定)关系是这种不确定性的数学描述。

然而,玻恩的概率波解释与实验表现出的波动物理实在性存在着深刻的矛盾。为此,以玻尔为首的哥本哈根学派及其尔后的追随者,为了消除其解释体系中的矛盾,作了大量的改进与发展,但却渗进了许多非常规的哲学思辨。在哥本哈根概率解释中,数学、物理、哲学思辨混合在一起,将人们带进了一个神秘的量子迷雾。几十年来,哪怕是最伟大的物理学家比如爱因斯坦也被卷进量子迷雾难以解脱。德布罗意、薛定谔、玻姆、布洛欣采夫等一批科学家曾试图用各自的解释取代哥本哈根解释,但终究没有取得主流学派的地位。量子测量问题,EPR 思想实验及量子概率等等疑问仍未得到解决。

看来量子力学数学形式的物理实质，还值得后人继续深入研究和探索。量子力学曲率解释，则是量子力学众多解释中，出自中国的一种新的量子力学诠释体系。量子力学曲率解释从波函数的振幅中分离出一个曲率因子，认为波函数描述的可以是人们通过实验现象，由物质波波长为微观客体建构的"形"的变化规律。每一个时空点上有一个与微观客体的"形"相对应的曲率在变化。"形"大，"形"内找到点粒子的概率小；"形"小，"形"内找到点粒子的概率大。因此概率和"形"(曲率)可以转换。曲率解释承认内秉概率解释的有效性，但进一步深刻指出：波函数是曲率波，曲率的大小表示粒子性，曲率的变化表示波动性。量子力学曲率解释有着从哲学、物理学、实验现象、数学到诠释体系的逻辑一致性，由哥本哈根概率解释缘引出来的诸多悖论在量子力学曲率解释中将不复存在，而且曲率解释可以把概率解释的合理部分纳入其中。

第一节　玻恩概率诠释与概率几何化

一切被严肃考虑的量子力学解释都是从玻恩概率诠释开始的。由玻恩规则，我们可从量子力学标准形式理论出发，预计测量结果的概率。玻恩规则对量子力学态的诠释在实验上是如此成功，以至于它本身亦被认为是该理论的一部分。但承认玻恩概率诠释，并不等于对量子概率的物理意义与哲学意义在量子力学基础研究领域达到了一致理解。事实上，正是对玻恩概率作不同的解释，开始了各种量子力学解释之间的分歧。量子力学的解释理论发展到今天，经历了将近八十年的发展，主要成活下来而被广泛讨论的量子力学解释中，玻姆因果性理论，退相干解释，相对态解释，模态解释，哥本哈根—冯·诺依曼解释，最低限度的统计解释等等，它们大概可按照添加解释性要求的由多到少和解释力的由强到弱的顺序进行排列。它们已使许多有关量子力学形式理论的特征问题和许多量子现象固有的本性得到了深入的讨论和理解，并各自从某一方面揭示了过去不为人们所重视的量子实在的形而上学基础。然而，在量子力学解释理论中，有一种倾向——量子概率的几何化是值得注意和重视的。

法国数学家、突变论的创立者托姆曾把波函数看成形态结构函

数。托姆在1972年出版的《结构稳定性与形态发生学》(中译本于1992年8月由四川教育出版社出版)一书中,批判了量子力学点粒子模型,提出了把波函数φ视为按一定频率改变拓扑类型的超曲面上的形态的观点。托姆对量子力学波函数做了几何解释。[1]

范・弗拉森在他的《量子力学:一个经验者的观点》一书中,介绍了他的几何概率简化模型,证明了概率的几何转换,可用来表示任意维的希尔伯特空间中的量子条件概率。

桂起权倡导的武汉科学共同体,在讨论量子力学曲率解释的合理性时,对量子力学几何化方法形成了共识。万小龙在仔细考察毕达哥拉斯关于理论建构的方法论之后,认为毕达哥拉斯关于理论建构的方法论,有三步四要点[2]:①从数的元素到数(a～b);②从数到形(b～c);③从形到可感物的对应(c～d)。

如果把毕达哥拉斯方法论中的每一要点均加上关系,例如改数的元素为数的元素关系,那么对波函数的解释也可参照修正了的毕达哥拉斯方法论:从数的元素关系到数的关系,再经形的关系到可感物的关系。例如,在量子力学的解释理论中,波函数概率诠释可看做是对波函数这个数的元素关系所作的数的关系的解释。

(a)	(b)	(c)	(d)
数的元素关系	数的关系	形的关系	可感物
波粒二象性	矩阵力学、波动力学	冯・诺依曼抽象空间	可观察的值
波函数	玻恩概率诠释	?	可观察实在

显然从上表可见,在对波函数的解释中,缺少相应的环节(c),即形的关系,而将(b)直接跳到了(d)。虽然在对经验预言上没有问题,但却留下了许多解释上的困惑,这表明基于波函数测量的概率解释不可能是完备的解释。因此,如果我们要明确波函数的物理意义,并给予测量结果的微观粒子的实在论(不仅是可观察量的值)解释,就必须先给波函数概率(数量关系)解释以形(空间几何关系)的再解释。

赵国求独立地并略早于托姆提出了波函数的另一种几何化设

想——量子力学曲率解释。他最初的成就是从测不准关系、物质波波长和氢原子玻尔半径等概念中综合定义了曲率，并从各类波函数的振幅中直接分离出曲率因子[3]，证明波函数是曲率波。这是一种以建构微观客体"形"为目标的几何化方向，尽管与托姆、范·弗拉森的方法不同，却可以更好地表示量子力学描述的物理实在。

第二节　量子力学曲率解释

什么是量子力学曲率解释？曲率解释的基本思路是什么？

量子力学曲率解释的基本思路可简述如下：承认微观客体不是质点，经典力学中质点抽象原则不能适用于原子世界（或不能照搬）。对原子中的电子等微观客体进行质点抽象，质点是虚的，波是实的。现有量子力学中，质点对应的具有唯象意义上的等效结构，以曲率波的形式，体现在理论的结果中。

量子力学曲率解释认为，原子世界，微观客体的"形"虽然直接看不见，但可以通过实验现象，理论和逻辑推理进行建构，而且被建构的"形"在讨论原子问题时，其大小不可忽略。量子力学中波函数描述的是微观客体自身"表面曲率"的变化规律。波函数是曲率波。曲率的大小表示粒子性，曲率的变化表示波动性。这是对质点模型的重大修正。

量子力学曲率解释可从电子的"光形转换"，"形的定量建构"和"形点转换"三个层面建立其诠释体系。

一、光形转换

在宏观世界，经验中的客体都是肉眼可见的，客体的"形"是通过观测信息（连续发光）由人眼—脑系统这架生物仪器建构的，至多增加了人工仪器的延伸作用。可以说，这是物理实在的"本体"通过光的连续作用，由人眼—脑系统直接认知的"客体"，是光将客体的"形"，在人脑中实现的一次转换。我们称为宏观的"光形转换"。宏观客体的"形"，经验上一般认为是不变的。而微观世界，特别是原子中，电子等微观客体不但我们直接看不到，就连"仪器的延伸"也看不到。然而，电子的"自在实体"——"本体"，及其在原子中的"形

象"——"现象实体"最终仍然只能通过原子发光来识别。原子发光是电子跃迁的产物,但我们知道的却只是电子跃迁时发出或吸收的光的频率和强度,它是不连续的光谱线。不连续的光不能给大脑建立一个连续的电子形象。人们曾经想象原子像葡萄干,电子像沙粒镶嵌其中,后来又想象电子像光滑的小球,形状不变,绕原子核旋转,像行星绕太阳转动一样。实验证明,这些想法都是错误的。量子力学引进了波函数,描述微观客体的波动性,与实验符合得很好。这是一个成功。但量子力学仍把一个不知道"形"是什么的电子抽象成了一个质点,我们认为这是当今量子力学哥本哈根解释产生诸多认识矛盾的重要原因。[4]

看来,为原子中的电子建构一个合适的"形"是问题的关键。电子在能级跃迁时发出的是不连续的光谱线,人的眼—脑系统无力直接识别其"形",但我们又必须通过光来认识电子的形象!这就只能是利用原子发光的频率和强度,由经验、知识、理论和逻辑推理进行建构了。这种建构只要能还原成现象并与观察不矛盾,它就应是理论所描述的物理实在。

为建构原子中电子的"形象",我们用曲面弯曲程度对发光(或反光)强度的变化加以类比,并建立如下对应关系:①发光(强度)为零,对应平面,曲率为零;②发光弱,对应曲面,曲率小;③发光强,对应曲面,曲率大。对微观客体的描述,可用"曲率模型"代替"质点模型"。

这样,原子中电子跃迁时的发光强度,就与要建构的电子"现象实体"在某一能级的几何"形象"发生了联系。由于原子不同能级的发光强度不一样,与电子联系的"曲率"就是可变的,因此,原子中电子的"形"也是可变的。原子中不断跃迁的电子,其"形"在运动中是可变的,这与宏观现象很不一样。宏观的"光形转换"与微观的"光形转换"有着重要的差异。但被构建的微观"现象实体",通过量子测量可以转化为宏观的可观察的"现象"或"现象实体"。

我们称上述模型为曲率模型。"曲率模型"实际上就是一种"场论"模型,是被"涂抹的质点"。它更为明确地为微观客体建构了一个可追踪的"有形"的研究对象。

二、原子中电子"形状"的定量建构

(一)氢原子波函数的启示

氢原子的径向波函数一般写为:

$$R(r)=\alpha B_0 e^{-\rho/2}\rho^l \angle_{n+l}^{2l+1}(\rho)$$

式中:$\alpha=2/na_0\quad \rho=\alpha r=2r/na_0$

$$B_0=-b\frac{(2l+1)!(n-l-1)!}{[(n+l)!]^2} \tag{1.1}$$

通过一定的运算上式可变为:

$$\begin{aligned}R(r)&=R_n 2B_0 e^{-R_n r}\cdot(2R_n r)^l\angle_{n+l}^{2l+1}(2R_n r)\\&=R_n\cdot G(r)\end{aligned} \tag{1.2}$$

式中 $R_n=1/na_0$,a_0 是玻尔半径,n 是能级量子数,R_n 具有曲率的量纲。R_n 是波的振幅(R_n^2 刚好是电子的"表面曲率"),氢原子的波函数可看做是曲率波。

(二)氢原子中电子的"形"的建构及"形"与曲率 R_n 的关系

氢原子中电子在能级 n 上德布罗意物质波波长

$$\lambda_n=\hbar/p_n=na_0 \tag{1.3}$$

λ_n 刚好可看做以 λ_n 为圆周长的相位圆的半径,R_n 刚好是圆的曲率。它就是公式(1.2)中的 R_n。所以,氢原子每个能级 n 由德布罗意物质波波长定义了一个与电子对应的曲率 R_n,我们称其为基准曲率。$r_n=na_0$ 称为基准曲率半径。它通过光的频率和强弱给出电子在氢原子中每个能级上的基本形象。氢原子波函数实为以 R_n 为振幅的曲率波。它给出电子的"结构"信息。波函数的简化形式 $R_n\cdot G(r)$ 或 $R_n\cdot G(x)$ 表明每个时空点上有一个曲率与电子对应。在实验现象上表现为发光的强弱和电子跃迁(或散落)频率的对应。氢原子中不同能级上电子的运动形态是可变的。借助于 R_n 或 $R_n\cdot G(r)$(或 $R_n\cdot G(x)$),可以对电子的"形态结构"做出分析和认知。

其他的任何物质波波函数其振幅中均可分离出一个由物质波长 λ_n 定义的曲率半径 r_n 及曲率 R_n。上述氢原子的分析具有普遍意义。(见附录 3)

三、形点转换

在原子中,我们利用每个能级上德布罗意物质波长 λ_n,为电子

建构了一个基本“形象”。并由曲率 R_n 表征。我们将要证明，原子中为电子建构的“形”，在讨论原子的问题时，其“形”不可忽略，不符合宏观质点抽象原则。若硬要做质点抽象，这个质点将是虚的，在“形”内任意一点都可以存在，没有运动轨迹，而波却是实的。很显然，电子的“形”越小，曲率 R_n 越大，在“形”内找到“点粒子”的概率越大；电子的“形”越大，曲率 R_n 越小，在“形”内找到“点粒子”的概率就越小。电子在每个能级上的基准形不同，其出现的概率也就不同。在每个时空点上的曲率在变化，因而出现的概率也就在变化。概率和曲率是可以相互转换的。

这就是我们说的“形点转换”。

量子力学曲率解释中的“形点转换”承认内禀概率解释的有效性，曲率解释可以消除概率解释的全部矛盾，并把概率解释的合理部分纳入其中。曲率解释与概率解释相比，理论描述的物理实在，认识上更加深刻更加全面：波函数本质上是曲率波，曲率的大小表示粒子性，曲率的变化表示波动性，曲率和概率可以相互转换。波动性和粒子性统一在同一模型中，波粒二象性在微观客体自身有了和谐的统一。量子力学曲率解释有着从哲学、物理学、实验现象、数学到诠释体系的逻辑一致性。

四、电子的“形”与电子位置的测不准

由海森伯测不准原理，原子中每个能级上电子的动量测不准量 Δp_n 和位置测不准量 Δx_n 应满足关系式

$$\Delta p_n \cdot \Delta x_n = \hbar \tag{1.4}$$

讨论原子中的电子，一般认为电子的动量就是电子的动量测不准量，因此有

$$\Delta p_n = p_n \tag{1.5}$$

结合(1.3)式，我们得到(相位圆的半径)

$$r_n = \lambda_n = \Delta x_n \tag{1.6}$$

由测不准关系知，Δx_n 的物理意义是点电子的位置测不准，这个测不准量刚好等于我们建构的电子“形”的“曲率半径”。测不准量正好体现了原子中电子的“形”不可忽略，(与原子的“形”$r_n = n^2 a_0$ 相比较)质点抽象原则不适用或不能照搬这一基本思想。测不准关系有

了实在论背景。它体现了内部空间与现实空间的一种内在联系。

必须指出，我们这里所说的电子的“形”是一种光学现象的建构，不能等同于经典力学意义上的“实体结构的点电子”，相反它转移了经典力学中“质点”承担的力学性质，它是一种“结构波”，不存在计算电子“自能”的认识上的困难。我们建构的“形”，实际上就是“质点对应的等效结构场”，经典力学中（包括现有量子力学）质点的一切实体属性，都体现在场的理论结果中。因此实体质点在量子力学中所表现的一切认识矛盾，在这里也就得到了基本的消除。

第三节　量子力学曲率解释实在论哲学基础

一、相互作用原理与相互作用实在

广义相互作用原理是指事物间的普遍联系。

狭义相互作用原理指出：自然界中一切物体在时空中的“形象”和“状态”都是由物质间的相互作用形成的，既包括四种基本相互作用（引力、电磁力、强力、弱力），也包括人类观测世界使用的观测信号作用。狭义相互作用原理是量子力学曲率解释建立的哲学基础。

由狭义相互作用原理我们得到两个推论：

推论一：没有相互作用，“物质本体”无以形成被观察的时空形象。

推论二：时空变化之所在，即物体之所在，也是场源之所在。

由狭义相互作用原理及其推论我们得到“自在实体”和“现象实体”两个基本概念。“自在实体（本体）”是离开人的主观意识之外的客观存在，它是抽象的、非具体认知的；“现象实体”是“自在实体（本体）”通过四种基本相互作用（引力、电磁力、强力、弱力），并借助观测信号作用于人体这架生物仪器及“人工仪器”的延伸形成的，它是具体的，被认知的。而人类对自然界的认识有三条基本途径，一是通过感官经验直接建立；二是通过感官和感官的延伸建立；三是通过现象、知识、理论及相应的逻辑结构间接建立。虽然它们的认识层次不同，但都是对实在的建构。不过，前两者是经验或者经验加理性层次，后者是理性层次。时空概念是人类根据“自在实体（本体）”和“现象实体”综合抽象形成的概念。体现物质的广延性和运动过程中的

持续性。时空既有不变的属性，也有可变的属性，主要取决于人类不同的认识层次。牛顿力学、相对论力学和量子力学都有各自不同的时空基础，表明人类对自然的不同理性认识层次。

相互作用是事物和现象的普遍联系形式。“实体是它自身的原因”（斯宾诺沙），“相互作用是事物的真正的终极原因”（黑格尔，恩格斯）。[5]可见，事物是在相互联系，相互作用中表现其存在的。根据广义和狭义的相互作用原理，我们提出了相互作用实在论或相互作用建构实在论，并认为它是当前世界流行的结构实在论中的一个版本。

二、区分微观作用机制与宏观作用机制

没有相互作用，“物质本体”无以形成被观察的时空形象。可见，自然界中力的相互作用是产生宏观和微观自然现象的共同基础。但由于微观世界和宏观世界在作用机制上有着本质的区别，因此，宏观现象与微观现象的产生机理又有着本质差异。微观世界具有量子特性，能量是不连续的，相互作用是间断的（$h\neq0$）。根据狭义相互作用原理，客体的“形”是通过相互作用提供给人们的，那么，微观世界中由相互作用提供的“形”和“状态”，在上下两个能级间就是不连续的、间断的、离散的。这就形成了独立的相干波源。“形”的突变性表明，“形”在突变演化中上下能级间的中间过程不得而知，在数学上可理解为“上形”和“下形”彼此在对方的投影为零，这正是数学上建立正交系的必要条件。物理模型和线性方程的数学形式有了协调统一。这里“上形”和“下形”就成了正交系的坐标轴。突变的特征被坐标原点掩盖“折叠”起来了（我们称其为时空盲区）。量子力学中，希尔伯特空间具有了真实的物理意义。但量子力学同时还约定，“上形”和“下形”自身均是线性、连续、单值周期函数。这表明在每一能级自身又预设了连续作用机制并由此与宏观世界相联系。由于坐标轴能够描述“形”的变化特征，因此波函数本质上是描述微观客体广域分布形态的变化规律的。人类的眼—脑系统无能力识别这样的“无形”客体。

在宏观世界（或经典力学中），相互作用（引力、电磁力）被看做是连续的，能量的变化也是连续的，即可以认为作用量子 $h=0$。宏观世界由相互作用提供的人类对“形”的认识不存在突变性，没有“上下

能级间断"概念。客体"形"的变化也是连续的，由能量高低差异所构成的状态变化，不构成"物理"上的正交性。"形"具有局域性，而不是广域、离散地分布在整个空间。这正是宏观经典粒子局域"形"形成，并与背景时空分离的物理机制。人类的眼—脑系统有能力识别这样的"有形"客体。

数学上非连续叠加符号 $\sum$ 与连续叠加积分符号 $\int$ 之间，从 $\sum \rightarrow \int$，是可以借助于无穷小分析工具而转化的，但物理上却发生了质的飞跃，变成了两类不同性质的事物。这正好体现了非连续作用过渡到连续作用物理上量变到质变的飞跃。反映了微观本质上的"突变"，向宏观现象上的"不连续"的转化。薛定谔方程正是描述了这两类不同性质的状态变化的方程。

三、区分微观质点与宏观质点的本质差异

由于作用机制的本质区别，宏观质点与微观质点其属性也有根本的区别。

在宏观经典力学中，所谓质点，就是在我们讨论的问题中，客体"形"的大小可以忽略不计，客体被简化为一个"质点"。力作用在这个质点上，客体具有的动量、能量、位置和时间都赋予给这个质点。这样，经典力学中的质点就具有实体的性质，质点运动的背景空间却是虚的。人们对在时空中运动的客体状态的描述，自动变成了对不同时空框架内质点运动轨迹的描述，而相互作用的连续性，又保证了运动轨迹的连续性，确保了微分、积分方程的数学应用基础。[6] 质点的能量、动量、位置和时间是确定的，而质点与背景时空的几何点重合，保证了质点（客体）运动的轨迹也是确定的。实验与数学方法的精确预见，也有了很好的对应。

在微观世界，原子深处宏观质点抽象原则不适用（或不能照搬）。原子的能级半径 $r_n{}'=n^2a_0$，而对应能级上的电子的基准曲率半径（相位圆的半径）$r_n=\lambda_n=na_0$，a_0 为玻尔半径，两者之比为 $1/n$。$n=1$，原子和电子"一样大"。即使 $n=10$，"原子"只比"电子"大 10 倍，人类目前还没有发现这样的原子。考虑电子在原子中的运动，将电

子抽象成质点，这恐怕已经不符合宏观经典力学的质点抽象原则了。电子的“形”已经不可忽略了，位置的测不准即已产生。分析表明，电子越靠近原子核，其“形”越不可忽略，电子的波动性越强；电子越远离原子核，其“形”越接近可以忽略，波动性就越弱。当 $n = \infty$ 时 $1/n = 0$，电子与原子相比，其“形”当然就可以忽略不计了。电子可抽象成宏观质点，表现出完全的粒子性。可见，原子外的电子，可以由经典电子论来进行描述。

由于原子深处电子的“形”，在讨论原子问题时不可忽略，因此，在讨论原子问题时，如果我们仍然借用宏观世界经典力学质点抽象方法，把电子当成质点，那么这个质点就具有宏观质点完全不同的性质。质点是虚的，波是实的，具有物理实在性。对原子中的电子作质点抽象，这个“虚质点”必须在其“形”的范围内存在，“形”不同，在“形”内找到虚质点的概率就不同（我们称之为“形点转换”）。“形”越小，概率就越大；“形”越大，概率就越小。这样，原子能级的发光强度，不同能级建构的电子“表面”基准曲率，对电子作质点抽象时微观质点在不同能级上出现的概率三者之间就具有一种正比例关系。于是，我们通过上述思维方式在“光形转换”及“形点转换”中，把海森伯的矩阵力学，薛定谔的波动力学（曲率的波动）及哥本哈根的概率解释在物理机制上联系起来了，而哥本哈根解释中的概率波性质原来是在对微观客体进行测量并作质点抽象时赋予的。按照我们的重新分析与理解，概率解释和海森伯的不确定性原理具有了实在论背景。这刚好证实了狄拉克的预言，[7]量子力学仍然是决定论的。对于赵国求的这种理解，万小龙称之为内禀非完全决定论，以区别于目前在量子力学哲学界较流行的决定论、非决定论和非完全决定论。

过去，尽管物理学家中的非决定论者和决定论者都承认有一个实体的电子存在，但由于他们谁也没有令人信服地说清楚这个既是粒子又是波的“电子实体”如何存在，这就为尔后的反实在论者提供了把柄与口实。按照他们的想法，干脆丢掉那个十分讨厌的“电子实体”，把微观世界中的某种“现象”看成是一种由经验所建构的抽象关系，这就斩断了实在论的逻辑链条，“电子实体”没有了，“现象”与“关系”却保留着。这样人类苦苦追求“实体电子”的痛苦好像随之消失。这当然是一种精神解脱。但是，孰不知，虚化实体、强化关系的思维

方法，最终将连人类自身的存在也成了问题，人类将陷入更深的痛苦之中。量子力学曲率解释的研究表明，“斩断逻辑关系”的做法只是一种无奈，其实人类有办法接上被斩断的逻辑链条，量子力学曲率解释就是一种尝试。量子力学曲率解释是实在论的。强化关系的“扭结”，虚化关系是量子力学曲率解释与反实在论和关系实在论的根本区别。[8]

物质本体是离开人的主观意识的客观存在。相对论中的静能 m_0c^2，康普顿动量 m_0c，及量子力学中的康普顿波长 $\lambda_0(=\mathrm{h}/m_0c)$ 都是客体相对坐标系静止时的不变量，人类无法直接感知，这类似于我们赋予“自在实体”——“本体”的性质。能量的变化、动量的变化、波长的变化都与人的主体地位相关，它们都具有建构的特征，而 $r=\lambdabar=\hbar/mc$（m 为动质量），$m=m_0/\sqrt{1-v^2/c^2}$ 是相对论条件下，连续作用中“现象实体”表现出来的性质。[9]“本体”、“现象实体”与“现象”有着重要的内在联系。

四、区分量子概率与经典概率的本质不同

牛顿力学中物体被抽象为质点，形的大小和变化对时空的影响忽略不计，时空是绝对的；相对论力学中，可以做出详细论证，客体运动引起观测形象变化对时空的影响，由洛仑兹变换变换到背景时空中，[10]客体变成了质点，时空却是变化的；量子力学中客体运动引起观测形象的变化通过 $dv=|\psi|^2d\tau$ 变换之后，被积分空间有曲率属性，是实体的，波动的，数学上由希尔伯特空间来描述。

经典概率中由客体抽象出来的“质点”具有实体性质，它遵从帕斯卡叠加原理，通过双缝后的图像是单峰的，概率的数学表达式 $p=|\psi_1|^2+|\psi_2|^2$；量子概率中由客体抽象出来的质点是虚的，具有不确定性，反映微观客体形的变化规律的曲率波是实的。通过双缝后屏上的图像是多峰的，不遵从帕斯卡叠加原理，数学表达式 $p=|\psi_1|^2+|\psi_2|^2+$ 干涉项。虚的质点通过双缝的哪一缝无关紧要，因为宏观经典力学中赋予质点的属性均赋予了曲率波。双缝后的波函数具有双重属性，曲率可转换成概率，曲率波中包含有概率属性。显示屏上点粒子落点的概率由波函数的概率属性决定；虚点粒子向实点粒子的转换由波函数的空间属性决定。量子测量中，仪器与被测系统的

相互作用——宏观连续作用的介入，是消除独立相干波源，使“离散波动形态”向“局域粒子形态”转换的重要条件。显然，这个转换有一定的过程，不可能突变，测量前后的波函数有了关联。是宏观仪器连续作用的介入，促成了波函数的“自我纠缠”，形成“自纠缠态”。波函数的“自身纠缠”就是“形”的自我纠缠，体现在相互作用中测量前的波函数如何转换成测量后的波函数。这个过程就是退相干过程。在新的环境中，若“形”可以忽略，“虚质点”就有了“实体性”的归属。量子测量完成了微观客体从遵从量子概率到遵从经典概率的转化。通俗地说，“上帝掷硬币”，可以掷出正面，也可以掷出反面，还可以掷出正面＋反面同时出现（加干涉项）的状态；而人类掷“硬币”，则只能要么掷出正面，要么掷出反面。量子测量则是完成“上帝”向“人类”的转化。

由于我们把曲面曲率的变化与原子发光强度的变化联系到一起，曲率大的地方发光强，曲率小的地方发光弱，而光的强弱与客体的“可视程度”相关。这又使人们可将概率（可能性）与被观测客体的可视度（视觉经验与“形”的建构）相联系。电子在某处出现的频率高，可视度亦高，反之亦反。我们称之为概率的可视度解释。概率的可视度解释是原子世界量子概率的重要特征。它既表明我们在原子中（或屏上）某处找到微观粒子的概率（或可观察性），也表明微观客体在该处造成的光学特性的变化。可视度的连续变化特性，刚好对应前文所称，约定每个独立能级上电子“形”的变化的连续单值性。概率的频率解释是宏观经典概率的定义，概率的可视度解释克服了宏观与微观概率定义上的混淆。

薛定谔方程描述的是牛顿时空中微观客体两类不同质的“形”的变化规律的波动方程。原子中波函数实施归一化之后，由本征态构成基矢的希尔伯特空间是波动的，具有实体性质，质点是虚的，飘忽不定。这样的质点也不具有实体轨迹的特征，它是“实体质点”的“幽灵”。双缝的干涉由空间的波动性来实现，虚的电子“幽灵”通过哪个缝再也无关紧要了。双缝干涉实验得到了圆满解释。

总之，描述微观世界的薛定谔波动方程不是描述微观客体质点运动轨迹方程，而是描述对微观客体建构起来的“形—曲率”的变化规律的方程——曲率变化的波动方程。不能说微观客体自身运动没

有轨迹，而是我们通过实验无法建构它的轨迹运动，我们通过实验建构起来的是对其“形”的变化规律的认识，并且可转化成不同时空点上“电子”出现的概率。

五、揭示宏观时空与微观时空的不同属性及描述对象描述方式的区别

现在我们有理由将牛顿时空、相对论时空、量子力学时空作一区分。

牛顿时空：牛顿时空的显著特点是物体与时空背景分离，时空是绝对不变的虚空。人类用感官直接建构起来的客体的“形”被认为是不变的，对背景时空无影响。在讨论的问题中，如果物体的“形”可忽略不计，则物体可抽象成质点，质点与背景时空的几何点重合，质点具有客体的全部属性，动量、能量、位置和时间都是确定的。对客体运动状态的描述，就是对质点运动轨迹的描述。在牛顿时空中，可以认为作用量子 $h=0$，光速 $c=\infty$，质点是理论描述的物理实在。

相对论时空：相对论的本质是看到了时空性质与物体的运动状态不可分离。但是，当把物体因运动状态的不同产生的“形变”(长度在运动方向上收缩——洛仑兹的观点)对时空的影响转换成与运动物体联系的坐标系的时空的变化时，物体自身的“形”就又可看作不变。人类对时空的认识发生了新的深刻变化。在讨论的问题中，如果“形”可忽略不计，则物体可抽象成质点，相对论力学仍然是质点力学。狭义相对论中，质点有实体属性，但时空与物体的运动状态相关。这正好抓住了时空概念产生的实质。相对论力学中对物体运动状态的描述，也是对质点运动轨迹的描述，不过，不同运动状态的坐标系，时空的记录不同。

狭义相对论时空中，亦可以认为作用量子 $h=0$，光速 $v=c$，理论描述的物理实在仍然是质点。广义相对论有重要变化，虽然 $h=0$，$v=c$，但时空弯曲，光走曲线。理论描述的物理实在除质点外还有“场”。

量子力学时空：一般，人类习惯于用宏观时空来认识微观世界的现象，预设了微观客体的“形”是不变的，可以和宏观客体一样从背景空间分离出来并抽象成质点。这是量子力学产生诸多认识困难的根

本原因。[11]对于电子之类的微观客体，人们不能通过感官直接建构它的“形”，只能通过原子发光现象和物质波波长间接建构。研究表明，讨论原子现象，对微观客体作质点抽象时，为微观客体建构的这个“形”对讨论的问题影响不可忽略不计。这样，一方面，使得客体与背景空间不能局域分离；另一方面，若要分离，只能分离出一个具有“不确定性的虚质点”和与微观客体相联系的“形”的变化特征。在微观原子世界，空间是实的，有波动性，质点是虚的，有不确定性。量子力学最本质的特征是 $h\neq0$，作用不连续。量子力学中光的性质也可分成三类：①作用量子 $h\neq0$，光速 $v=\infty$，时空平直，光走直线。②作用量子 $h\neq0$，光速 $v=c$，时空平直，光走直线。③作用量子 $h\neq0$，光速 $v=c$，但时空弯曲光走曲线。不同认识层次量子理论表述的形式虽有不同，但曲率波、虚质点是原子世界量子力学描述的物理实在。波函数是客观的，但不是实在的矛盾解决了。

量子力学还可以通过归一化，把微观客体的形变属性变换成希尔伯特空间的空间属性。

令
$$c = 1/V, dV = |\psi|^2 d\tau \tag{1.7}$$
归一化系数 $c = 1/V$ 表明归一化是求 V 空间的体积比。(1.7) 式是 V 空间（量子力学希尔伯特空间 —— 冯 · 诺依曼的组态空间）与牛顿空间(τ) 的变换，V 有能级概念，是对牛顿空间虚空特性的改造，具有真实的物理内涵。我们称其为结构空间。结构空间随曲率 R_n 的变化而变化。对 V 中的自由变量(x,y,z,t) 作洛仑兹变换，薛定谔方程就过渡到狄拉克方程。量子场论中的真空特性应是 V 空间的特性。

量子力学中态的跃迁是突变的，它与牛顿力学的超光速($v=\infty$, $h=0$)，狭义相对论中的光速有极限($v=c, h=0$)，都是人类在认识世界描述自然现象时，根据实验现象对观测信号所做的逻辑约定。由此可见，人类在对世界统一图景的追求中，我们能做的是把不同认识层次有机地合理连接起来（找到不同层次间的逻辑万向节），而不是把作用机制不同的认识层次，强行归于某一层面之中。

总之，大半个世纪以来，量子力学对微观世界的描述确实取得了惊人的成就，然而，量子力学造成的解释性疑难和与相对论的深层次矛盾——决定论与非决定论，定域性与非定域性矛盾依然存在。曲率解释完全承认概率解释的合理部分，但它进一步认为，量子力学解

释问题的困难，关键在于忽视对微观客体，比如电子等微观客体“形”的建构及宏观质点抽象原则在微观世界的不合理应用。曲率解释虽然在物理上和哲学上还需进一步深入研究，但它试图从概率几何化出发，以统一的眼光揭示牛顿力学、相对论和量子力学的物理模型理想化方法的共同特征，可能对量子力学解释的发展具有重要的启发意义。

参考文献

[1] 雷内·托姆. 突变论：思想和应用[M]. 周仲良，译. 上海：上海译文出版社，1989：215-280.

[2][3] 赵国求，桂起权等. 物理学的新神曲[M]. 武汉：武汉出版社，2004：170、279.

[4] 坂田昌一. 坂田昌一科学哲学论文集[M]. 安度，译. 北京：知识出版社，1987：140.

[5] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：215.

[6] 赵国求. 经典力学与量子力学作用机制的本质差异与量子测量问题//科技导报[J]，2003(2).

[7] 狄拉克. 物理学的方向[M]. 张宜宗等，译. 北京：科学出版社，1981：9.

[8] 赵国求. 相互作用原理及其认识论逻辑基础//国际学术动态[J]，2001(5).

[9] 赵国求. 康普顿物质波与量子力学曲率解释//武钢大学学报[J]，2000(1).

[10] 赵国求. 量子力学曲率解释//科技进步与对策[J]，2000(11).

[11] 赵国求. 经典概率与量子概率//科技导报[J]，2003(4).

Chapter 2
Evolution of Theories on Substance and Scientific Viewpoints on Space and Time

2.1 Substances—Original Beings of the External World

What are substances? Substances are original beings of the external world, different and abundant materials, objects, systems and their properties and relations. Physicists and materialist philosophers must admit that substances are the first research objects of philosophy at the lowest conceptual level, in physical philosophic theory system.

Human cognition of substances has undergone a long and difficult process of mentality.

The "Qi", a concept in traditional Chinese culture, contains our present concept of substance. The concept "Qi" originated and appeared in the latest years of Xi Zhou Dynasty; Xunzi, an ancient Chinese thinker, believed that "Qi" formed the common basis of all things in the universe, including human beings. Wang Chong, another Ancient Chinese thinker (in East Han Dynasty), remarked: "If Qi from heaven and the earth join together, all things can grow by themselves", which not only took "Qi" as substances (things), but also contained the harmonious motion of "Qi" (substances). To put it into today's expression, "when Qi from heaven and the

earth are harmoniously integrated together, all the substances (things) will naturally come into being". There would be no ambiguity to regard "thing" as a stable motional parallel form originated from substance motion and changes. So, "things" originated and developed by the mixture of "Qi" formed a stable dynamic balanced "substance" system. Such ancient Chinese thinkers as Zhang Zai (in Song Dynasty) and Wang Fuzhi (in late Ming and early Qing Dynasties) believed that "Qi" was the origin of all things, and they even gave a full play of Qi with monism. Chinese medicine particularly emphasizes the function of "Qi" in human body: without image or structure, the smooth movement of "Qi" is the fundamental insurance of human health. All things come from "Qi", and return to "Qi". Chinese "Qi" monism, by exhibiting the evolution of Qi, has put forward a kind of generating model of universe. [1]

In present physics, the idea of "field" is interlinked with ancient Chinese natural view of "Yuan Qi" (the origin of air). Zuoxiu He, academician of ASC (the Academy of Sciences of China), believes, "the theory of the Yuan Qi should be the origin of contemporary quantum field theory. "(Journal of Dialectics of Nature, 1979:(1):87)。

As to life mechanism, Mr. Guoqiu Zhao believes that, in Chinese medicine, "Qi" is the vigor of life substance and presented by the motion of living substance, and it contributes to the stability of the system. Vitality depends on vital force, which is also the totality of vital energy, life-propelling force, and biotic potential. The substance motion condition and structural components beneficial to the stability of system are healthy "Qi", and the substance motion condition and structural components harmful to the stability of system are perverse "Qi". "Yin" and "Yang" (two opposing concepts in Chinese philosophy, medicine, etc.) are state parameter of living substance motion. "Qi" fluid is the flow of substance, energy and information and transfer of substance motion in human body.

And this gives "Qi" scientific connotation, not mysterious concept in non-science history. If human body is regarded as a rather stable dynamically balanced system (the healthy self-stable state), "Qi" will then play a very important function in the health and stability of life ("Yin" and "Yang" balance). As to non-life system, "Qi" can still be defined from the stability of "substance system". The substance motion condition and structural components beneficial to system stability are healthy "Qi", or vice versa, which is in agreement with the concept of "Qi" in traditional Chinese culture. [2]

Besides "Qi" original being, in Chinese traditional culture, there also existed "Tao" original being with "Tao" (a term in ancient Chinese philosophy, meaning: original being) of Laozi (Famous ancient Chinese thinker) as its centrum. Mr. Wulun Jin believes that, "Tao" is more fundamental than "Qi". "Qi" is intermediate state that "Tao" transits from virtual state to real state. [3] Guangbi Tong has refuted the viewpoint of "Tao" reality, and points out that "Tao" is not constructed substance. [4] "Tao" is "virtual", not image, and "wu" (nothing). Thus, Wulun Jin summarizes Laozi's thought of "Tao" as follows: ①"Tao" is the original being of all things in the universe, and all things come into being from "Tao". ②"Tao" produces all things without the help of external forces, or "the first propelling", but on its own power, and "the laws of 'Tao' is natural". ③"Tao" is virtual, without image. ④"Tao" producing all things is a process, and its nature is motion and change. ⑤"Tao" illustrates that the relation between coming-into-being and development is natural: everything comes into being and develops on its own. Based on it, Guangbi Tong and Wulun Jin summarize "the theory of becoming-to-be" in traditional Chinese culture and believe that "the theory of becoming-to-be" is the mainstream in the Orient.

Philosophically, as original beings that construct (or generate) everything in the world, substances have hardly any exact image

and state. Substances are the totality of abundant materials, objects, systems and their attributes and relations. In this sense, "Tao" is the totality of substance motion condition and laws, and it has no cognitive contradiction with "virtual Tao", "no-image Tao" and "Tao-fa-tsu-jan" (Laws are natural).

Tao's nature is movement and change, "Tao-fa-tsu-jan". Because of Tao, everything comes into being and develops of itself, without outside aid, which is essential conclusion that movement (motion) is the inherent property of substances.

"Everything originates from being, and being from nothing," which indicates what is often said "being grows from nothing." Guoqiu Zhao believes that, to Laozi, "nothing" is not really nothing. Also, "no-image Tao" and "virtual Tao" should not be that "Tao" is nothing. "Virtual" and "no-image" beings are the counterpart of "real objects". Philosophically, "nothing" corresponds to what is before "being", and "being" is the state that is after "nothing". "Being" and interaction are the keys of the idea that "being grows from nothing." That "being grows from nothing" is a process that "virtual beings" change into "existing beings." That "being grows from nothing" is a process of change of substance motion, and a process that "things" originate and develop. Here exists the scientific connotation of Chinese traditional philosophy.

We believe that the theory of interactive constructional reality (put forward in this book), "things-in-itself" of Immanuel Kant or our "substance-in-itself" belongs to the similar concept as "nothing", while "appearance" of Immanuel Kant or our "substance of appearance" is similar to "being". The concept that "Being grows from nothing" corresponds to the transition of "substance-in-itself" to "substance of appearance". In addition, "substance of appearance" processes the attributes of construction. Outside "substance of appearance", we still keep the concept of "appearance". The theory of interactive constructional reality, one of the editions of

structure reality theory, can easily communicate with interactive theory of coming-to-be.

Mr. Wulun Jin also puts it that "Jin's demon is the demon of becoming-to-be". [5] I believe that, "Tao originates one; one produces two, two becomes three, and three gives birth to all substances", "three" is really "Jin's demon". "Three" is the direct cause of all substances. "Tao" decides one in its entirety, so one is the chaotic state of the whole universe; two is contradictive motion of the two opposite poles ("Yin" and "Yang") inside universe after its coming into being; and three is "gas mixture", that is, substances needed to form stable system and substance motion condition corresponding to stable and balance states. "Thing" is relatively stable dynamically balanced system obtained from substance motion and change. If "Jin's demon" combines with Laplace's demon, they will have cause-result decisiveness; with Maxwell's demon, randomness, and with Haken's demon, self-organization. "Jin's demon" is substantial agent that decides in what pattern substances "appear" in the world.

In addition to "Qi" original beings and "Tao" original beings, the ancient Chinese also suggested the ideas that five basic elements (including metal, wood, water, fire and earth) constructed all substances. As early as in Zhouyou King's time (about 2500 yeas ago), Shibo, an ancient Chinese thinker believed that, metal, wood, water, fire and earth were five basic substantial elements, whose cooperation formed various kinds of substances. That is, "combination of reality produces subject."[6] However, this simple substance construction theory gradually lost its original sense of the structure of matter, and was turned to symbol carrier of contradictive movements of all things later in the combination of "five elements" and "Yin-Yang". "Virtual Tao", "no-image Tao" and "no-image gas" also fell to the same fate. The Chinese did not follow the road of reductive thinking pattern of the structure of mat-

ter, which best explains the differences between West and East scientific cultural traditions. [7]

In the West, Aristotle, the ancient Greek philosopher, believed that all substances were composed of 4 elements (water, fire, earth, and gas). The elements were eternal, while "things" were the gathering or scattering of these elements. No vacant space was between the elements but a nameless fifth element wandering there. [8] However, Democritus, Aristotle's contemporary, believed that the original beings of everything were atoms and vacant space. "Atoms are what cannot be further cut apart and they move in vacant space. The birth or extermination of substances is the result of the combination or separation of atoms in vacant space. Like elements, atoms take up space but no time". [9] To put it in a more popular sense, "atoms" and "elements" suddenly appear there, and exist in the world without taking time to evolve, eternal and immutable. This feature of atom and element is in fact the ancient "particle", only that there was no such conception of "particle" then. The idea that all substances were constructed by gathering or scattering of unchangeable elements or atoms was named Western "theory of construction" by Mr. Guangbi Dong and Mr. Wulun Jin, which they believed was the mainstream. Presently, any efforts to explore the most elementary particle that constructs the world originate from the thoughts of "only space but no time" and their development. The best model to eliminate this sudden change of elementary particle is the wave particle duality model of microscopic particles, whose inner undulatory property extends time procedure into particle interior and gradual change of time can rely on the model, which eliminates the faults of cognition that "there is only property of space but no property of time". It is curvature interpretation of quantum mechanics that puts the starting points of space and time at the same starting point; and curvature model replaces point particle model. Matter wave is curvature wave; ben-

ding degree of curvature expresses corpuscular property, and curvature change shows undulatory property. Thus, in curvature interpretation of quantum mechanics, the wave particle duality of microscopic object becomes harmonious and unified. [10]

In the dispute of Democritus theory of atoms and Aristotle theory of elements, the theory of atoms was very difficult for the people of that time to understand and accept. As a result, it was left unnoticed for about 1900 years. However, there is no doubt the theory of atoms has won brilliant victories in the rapid development of the Western modern science. To the development and maturity of the theory of atoms, Pierre Gassendi, Galileo Galilei, Francis Bacon, Isaac Newton, and John Dalton all made great contributions. In the development of their theories, theory of elements and theory of atoms obtained an identical interpretation, and people found element was the generic term of the same types of atoms of the same nuclear electrical charge numbers. [11] Now more than 100 kinds of elements have been discovered, together with the artificial elements, and atoms are numerous.

The similarity and diversity of the theory of coming-to-be and construction theory lie in: whether in theory of coming-to-be or in construction theory, "objects" or "system" both need "productive" or "constructive" elements; there is substance motion and change in the process of production or construction of "objects". Between generated or constructed "thing" and "thing", the feature is ever different, which is their common ground. However, in oriental theory of coming-to-be, the property of elements is different and changeable whether they are inside "object" (system) or outside it; that is, elements in the "object" are not equal to elements outside the "object". While in construction theory, the property of elements is the same and unchangeable whether they are inside "object" or outside it; elements in the "object" are equal to elements outside the "object". Besides, the relation between the whole and

parts in the theory of coming-to-be has obtained new comprehension. The whole is bigger than the sum of parts, and new features will emerge from superposition of element. This is the essential difference between the theory of coming-to-be and constructionism. The theory of coming-to-be lays more emphasis on the motion and change of substance and their interaction, including the element itself of generated "thing" (or system).

Mr. Guoqiu Zhao believes, the whole can be reduced to parts, but the elements (sub-system) in "thing" and the elements outside the separated "thing" have important difference in nature, which is the important reason for the new feature suddenly to occur in the system. It will provide important cognitive basis for quantum mechanics and Chinese medicine.

"Field" is also a substance in motion.

"Field" was first introduced by Michael Faraday as a supplementary image to describe electrical interaction and magnetic interaction. When describing electrical interaction, Michael Faraday used some "interactive force lines" to formulate electrical function and property. The property of these "interactive force line" is the property of "electrical field" of Michael Faraday. Similarly, Michael Faraday also used the characteristics of "interactive force line" to describe magnetic function, and called it magnetic field. After that, the concept of field was used to describe other physical phenomena, such as temperature distribution inside substances, which was described as coordinate and time function. Fluid velocity distribution can also be described as velocity "field". Here, "field" is a mathematical function, which describes certain physical law distributing inside objects. "Field" cannot be separated from substances, but "field" alone is not "substance". People believed that, "Field" is purely a mathematical means which describes physical laws inside substances.

Since the birth of Maxwell electromagnetic theory, "field" was

to be regarded as a manifestation of materials. Theoretically, Maxwell proved the being of electromagnetic field, and Hertz confirmed its being through his experiments. At first, people believed that, like temperature field and velocity field, electromagnetic field spreads by means of medium and that is Ethernet medium. Substances move in ether without resistance or relative slither. People tried in vain to examine ether's property and to prove its being, and later, ether's being was denied after Michelson-Morey experiments. Finally, it was acknowledged that electromagnetic field itself was substance, and that its spread needs no medium.

After electromagnetic field and quantum mechanics were integrated, the humans had more profound understanding of the features of electromagnetic field. In 1905, Albert Einstein proved the property of light quantum for the first time, that is, light is composed of light quanta. Light is a kind of electromagnetic field which is doubtlessly substance. And in nature, strong interactive field (gluon field), weakly interactive field (intermediate boson field), gravitational field (graviton field) are all substances without any doubts, only that graviton of gravity field has not been found yet.

Field substances have their own motional velocity. The spreading speed of electromagnetic field is 3×10^{8} m/s. Nowadays, people also believe that gravitational field transmits in light velocity; gluon field and intermediate boson field are assumed to travel in light velocity. It is certain that "field" is a substance in motion.

Boson field possesses a very important feature, the mission of which it is to transmit interaction in substances: electromagnetic field transmits electromagnetic function, and gravitational field fransmits gravitational function; strong interaction is transmitted by gluon field, weak interaction by intermediate boson field. Without the "being" of these field substances, interactions between substances would not be realized. The velocity of "field" substances indicates that interaction between substances is transmitted in finite

speed.

In quantum field theory, fermion is described by fermion field while interaction-transmitting boson is expressed by boson field. Quantum field of ground state (vacuum) reveals zero-point vibration. Quantum field is stimulated into excited state, and quantum field de-excitation transmits relative microscopic particles. Quantum field is the new form of substance motion or moving substances. [12]

Material world is in eternal motion. Substances are the only subjects of motion. There is neither motionless substance nor motion without substance in the world.

Emergence of the modern field theory has supplied forceful evidence for Aristotle "non-vacant-world". However, whether ancient simple theory of atoms and its vacant world or modern scientific viewpoint of structure of matter (that substances are made up of molecules, molecules atoms, atoms atomic nucleus and electrons, atomic nucleus protons and neutrons, protons and neutrons quarks, etc), whether ancient simple theory of elements and its non-vacant world or modern elementary particle, quantum field theory, gravitation field theory and so on, all tried to discover original beings from material world itself and acknowledged that the material world existed independent of human subjective consciousness. This line of thinking is rational and it is this rationality that has brought about the rapid development of present science and technology. Nevertheless, the theory of atom, element theory, elementary particle, and field theory are not the totality of the substances cognized by materialist philosophy, but the reflection of certain level of cognition of substances in certain interaction. In the present, physicists are trying to narrow all the substances into one (such as superstring) or several elements (e. g. elementary particles) for their research—the matter structure research of substances in one or several certain actions of natural forces. In spite

that the research in the future proves the existence or non-existence of "original substance", the basic cognition of materialist philosophy about substance will never be changed.

German classic philosopher Immanuel Kant made a famous philosophic exposition on the external world existing independent of human subjective consciousness. He believed that all we perceived in the world was objective appearance; while the true features, e. g. , "thing-in-itself", were what our senses could not perceive and what we could only guess on our intellect and thinking. In Immanuel Kant's viewpoint, "thing-in-itself" was unknown while what was known was its "phenomenon"—appearance that "thing-in-itself" showed, or representation produced when substances functioned on our sense. He held it that unknown as "thing-in-itself" was, its being was out of question; without "thing-in-itself", its representation could not have been formed on our sense.

Modern scientific research also demonstrates that the humans can construct the appearance of "thing-in-itself" by using theoretic construction, which is called "substance of appearance".

Immanuel Kant's philosophy had some materialist components because he acknowledged the being of "thing-in-itself". However, what is unacceptable is that it simply regarded the true features of substances as unknown. Some things may be unknown today, but they may be known tomorrow; something may be not completely known today, but it will be known more completely and exactly, with the development of science and technology. The real appearance of "thing-in-itself" will be clarified and exposed in our ever deepening cognition. All of us are experiencing the simple and explicit transformation of "thing-in-itself" to appearance, or "thing-for-us". [13]

We oppose Immanuel Kant's agnosticism, which does not necessarily mean that we agree that the world we know is the totality

of the world. As a member of nature, in the long process of evolution, some parts of our physiological structure may have evolved, and some may have degenerated, in our perception of the world. Maybe, when we were still apes, we could percept external things in the world, but nowadays, we could not percept them any more owing to the vanishing of "wild nature"; what's worse, certain external things may never be sensed owing to our physiological structure. Fundamentally, such external things have been rejected by declined human physiological structure and physiological function. The hidden substances in the universe may be among them. This understanding of the material world reminds us not to be at a loss when new cognitive problems arise, and that some temporarily unknown substances may exist in the world. Besides, if the humans cannot perceive certain substance, it neither means that it does not exist outside the human consciousness, nor that "other beings" cannot perceive it. This certain thing (substance) outside the human consciousness should be the totality of the perception of all living things in the universe (including possible extraterrestrial intelligence). Man is only an ordinary member in perceiving the secrets of the outside world, without any absolute advantages. Of course, present facts show that the world in our mind may be more complete than that in the minds of "other beings", and the human beings can add to their own cognition by drawing support from that of "other beings", just to console themselves.

Besides, the world itself is of different levels. Universal, macroscopic and microscopic levels all have their own different mechanism and motion laws. The transformation of substance-in-itself to appearance and substance of appearance also has important relation with their own physiological structure of "species of living beings" and the features of medium used in observation. It may falls into obvious one-sidedness and bring cognitive puzzles to the human beings to use one layer of the human experience and thus formed logic

structure to conclude all the levels of the world, to pursue world's original beings and construct the origin of the world. This book will highlight this point.

Substance exists outside human consciousness and marks an objective reality, perceived, duplicated, photographed and reflected by our senses.[14] But how is this "thing-in-itself" duplicated, photographed and reflected through human sense? It involves substantial nature of thinking. Hundred years ago, it was too high a demand to understand human brain, and its reflection mechanics, from physics, chemistry, biology, brain science and neuroscience. Since the end of the 20th century, the rapid development of the research of brain science and neuroscience has provided substantial essence that reveals thinking with important scientific evidence. Substances exist independent of consciousness, while consciousness (thinking) cannot be separated from substances. Think, as a verb, reflects the motion process of brain nerve substances, and thinking, as a noun, reflects the motion patterns of brain nerve substances, and thinking content is nurtured in motion process and patterns of brain nerve substances. Study on neuroelectrical current shows, thinking at least corresponds to the structure of matter of electromagnetic field. The humans have succeeded in remote control through substance property of electromagnetic field of thinking.[15] Some important results of modern scientific researches show that substances not only exist independent of consciousness, but can be duplicated, photographed and reflected by consciousness as well. Consciousness is not innate, but determined by substances; consciousness duplicates, photographs and reflects substances, and it reveals the biological, physiological, chemical and physical mechanics of modern science. In this significance, substances are both outside consciousness and inside consciousness. The world is unified within substances, and it is materialist substance monism that we adhere to in ontological theory. French

philosopher Rene Descartes divided substance and thought into two, and put forward his dualism that consciousness and substances were independent of each other, which, in front of the achievements of modern science, was self-defeated and entered the museum of history of its own accord as human cultural relics for the public to appreciate. The antagonism between thinking and substances is caused by taking "thinking content (results)" as the equivalence of "thinking", the limitedness of which is obvious, not to mention the idealist world outlook that thinking (consciousness) determines substances. There is evidence that the current idealists, seeking help from science, puts scientific labels on theology so as to redeem it from declining, as in the case of religious theology begging for scientific certification.

2.2 Evolution and Features of Scientific Viewpoints on Space and Time

The human scientific cognition of space-time underwent a rather long process of historical evolution. To sum up, there are all together 4 historical periods: ①Flat (intuitive experience) space-time concept in the ancient times, ②Ancient spherical symmetry space-time concept, ③Isaac Newton absolute space-time concept, ④Albert Einstein's relativistic space-time concept. From historical point of view, the evolution of space-time concept, during pre-scientific periods or in scientific times, is accompanied with two important features: 1) reducing and diminishing its absoluteness, and 2) developing and improving its relativistic features. History proves that each scientific revolution of space-time knowledge will bring up great progress in science and technology. In the 20th century, the new leap in Albert Einstein's space-time viewpoint made great contribution to the advance of science and technology. In certain sense, the great change in space-time viewpoint is the premise and

basic sign of the great transformation of science and technology. As a result, the research in space-time viewpoint is of active significance.

Flat(intuitive experience) space-time viewpoint in remote antiquity . [16]

The human cognition of the nature invariably started from self-experience. In remote ancient time, because the humans had only very small sphere of activities and the productivity was rather low, they knew no more than the sky, the earth, the far-stretching flat ground; they could only draw the concept of flat ground from their direct experience, not to mention science and technology. For example, the house they lived was their immediate experience: the roof, the floor, and the four quarters, all this formed the idea of "space" in their mind. High mountains rose from the ground and hollows were below the ground, from which they knew that space extended up and down. In the house or outdoors, people could walk forward or backward, to the left or the right, which revealed that directions on the plane surface were relative and far-reaching, and they could move to any direction at random. However, the upper and lower directions were different: substances fell from above onto the ground and even into the hollow, while substances in the hollow could not "fall" up. Thus upper and lower "spaces" could not be reversed.

The ancients also made a further imagination of the flat space: plane land was placed on a turtle cove while the turtle was floating in the sea, so earthquakes were the result of turtle perturbation. Because there were upper space and lower space, the experience told people that if upper side was turned down, objects would fall. So, as long as the turtle turned, the humans would fall into a bottomless abyss. Also, top is overhead and bottom is under foot; thus, to draw flat ground away, all would fall without limit. The top and bottom of space were not equal, but absolute, with two ab-

solute directions.

In order to compare the size of space, ancient people needed to invent space measurement method. Initially, because they had no standard length unit, the result of their measurement was different. Some tribes used the foot length of their head as the unit, some used arm length, and then, when they changed their head, the measurement unit was different. Confusion arose when different results of the same substance were reached. Later, length unit was to be unified. In China, this great project was accomplished by Qin Shi Huang (First Emperor of Qin) (259—210 B. C.). Since then, the same substance began to have the same measuring result. In their effort to eliminate confusion in measurement, the ancients stood on a basic concept that the length of an object was fixed, otherwise, the unification of unit was meaningless.

This is the first progress in human cognition of space-time concept.

All natural phenomena are in motion and change. The elapse of "process" is the basic feature of natural phenomenon and human activity. Pan Gu (creator of the universe in Chinese mythology) and Christ both indicated the beginning of timing. From the elapse of "process", the humans drew the concept of time. The ancients noticed, all the processes of periodical changes could be used as measurement unit of time. The simplest periodical change was sunrise and sunset, full moon and crescent moon, and four seasons. Thus, chronographic units—day, month, year, etc. , appeared. Perhaps inspired by water leakage, the ancients invented a drip timer, chronographic unit was soon shortened to the process of a drop of water drip, which is close to our present minute or second. In their mind, "clocks" were the same, so measuring results should be the same; otherwise, the invention of "clock" was meaningless. The ancients also believed the length of particular "process of substance as fixed. In other words; in their daily experience, the

ancients were not clear what connection there was between "time" and substantial "motion".

Other characteristic of the ancient cognition of time is its one-way nature. The dead could not revive, which indicated the process was not reversible. Irreversibility of process brought about the idea of one-way nature of time. The flow of time is always from the past to the future.

Nothing is equal in value between up and down in space, and between passing and coming in time, and unchangeable characteristics of length and time intervals are what we mentioned the ancient flat (intuitive experience) space-time viewpoint.

The ancient spherical symmetrical space-time viewpoint. [17]

More than 2000 years ago, Aristotle and Claudius Ptolemy established "geocentric system". They believed the universe was a limited spherical body, circular earth lay still in the center, the sun, the moon and stars all moved around the earth, and that the moon, the sun, planets and stars were on different spherical shells; they were all making perfect circular movement. In Aristotle's theoretical system, the land on which the humans lived was not flat but spherical. This is the first great revolution in space-time viewpoint. The land the humans lived on was not flat but round—the concept of up and down on spherical body is not absolute but relative! One side of the sphere was regarded as the up side, and the other side should be the down side, and vice versa. The space concept of up and down was soon changed from the only linear direction of 180° to any direction of 360°! How could they imagine that the spacious land the humans lived on was changed to a sphere without strict directions? Obviously, it violated the direct human experience. It is really extraordinary that, at that time, Aristotle dared to break through the ancient views about flat space, proposed that the earth was spherical, gave the unified interpretation of the universe, and declared that experience was suitable within certain

partial scope. It can be inferred that a spherical Earth concept needed to overcome a resistance caused by rather great prejudice. Up and down are relative, any directions in space are equal in value, no any one direction is in specially favored condition—this is space direction relativity. From absolute to relative space directions, the human cognition of space-time made a key stride towards scientific space-time view.

Although directions were relative in Aristotle space-time, different points of space had different features, which was similar to flat space-time view. in Aristotle spherical space-time view, the absolute location of space was still absolute. In geocentric theory, the location of substance in the universe played a very important role. The center of the earth was the center of the universe; each object would try to reach its natural location if it met no resistance in its movement. The reason for substance movement was that it did not reach its natural location. The natural location of substances in the vicinity of the earth was the earth core, which, in Aristotle's opinion, was the real reason for falling movement. Thus in Aristotle space-time view, the earth core had a very special feature—this point played a decisive function in natural laws governing the substantial movement. This means space-time point is absolute. Although Aristotle space is of isotropic nature, the location of each point of space is not equal in value.

Basically, Aristotle theory is a qualitative one, almost without quantitative physical law, so it had no breakthrough in the cognition of time. Time was only accompanied by the passage of process, all time measurement of process had no connection with the selection of coordinate system; time was absolute and had one-way nature.

In short, compared with the remote ancient flat space-time view, Aristotle space-time view eliminated absoluteness of space-time direction, but kept the other absoluteness.

Isaac Newton absolute space-time view. [18]

Today, it is not difficult even for the middle school students to criticize Aristotelian geocentric theory. Before 16th century in the West, however, Aristotelian space-time view dominated for about 1900 years, during which time, science came to standstill, for his theory became a serious obstacle to scientific progress. Up to 16th century, Nicolaus Copernicus created heliocentric theory: the sun is in the center of galaxy; the earth and other planets move around the sun. "Geocentric theory" began to shake since. Later, F. G. Bruno, Galileo, Isaac Newton kept fighting for "Heliocentric Theory", for which F. G. Bruno even lost his life. Neo-science with Nicolaus Copernicus, Galileo, Isaac Newton as its representatives, refuted "geocentric theory". Isaac Newton's law of gravitation indicated,

$$f = G\frac{m_1 m_2}{r^2}$$

An apple may fall to the moon in the same way it falls to the earth. An apple falling to the earth and the moon moving around the earth are caused by the same reason. The earth core, like the moon's core, constantly changes its location in space. Galileo even made it clearer that the pattern of physics law has no relation with the choice of coordinate system of mutual uniform motion. As a result, in Newtonian mechanics the earth has no central position, and any space points are equal in value. Calculating from any space-time point, physics laws show the same. Space is regarded as a stage separated from substances for all substances to perform. Newtonian mechanic space-time view eliminated unequal rights of space-time points, and equal rights of space-time points brought about absolute uniform and straight space-time. Nevertheless, its absoluteness was eliminated in general theory of relativity.

As he had abstracted space, Isaac Newton abstracted time from the evolving process of substances, which became arbitrarily

elapsing objects separated from space and substances. In Isaac Newton's second law

$$m\frac{d^2x}{dt^2}=F$$

Given initial conditions, we will either know an object at present, or in the future, or even in the past. Time has no starting point, so its one-way feature is replaced by its relativity. However, we should notice, time reversibility of Newtonian mechanics does not mean that in Newtonian mechanics system, the dead could revive, but that time towards past or future is infinite. Time may either flow to the future or to the past. Direction of time flow is reversible in Isaac Newton's second law. This is the relativity of time flow.

Space-time view in Newtonian mechanics, compared with Aristotelian space-time view, enhanced its relative feature though reducing its absoluteness (but absoluteness was retained). Isaac Newton said: "Absolute space, in nature, has no relation with any external conditions and always maintains similar and fixed." "Absolute and pure mathematical time, in itself or in its nature, elapses evenly and has no relation with external conditions." Space can be separated from substance motion, so can time. Space has no relation with time, so on space-time stage, space distance and time interval are both absolute. In other words, length and time have no connection with the choice of coordinate system, and physical law is unchangeable in the form of coordinate system of relative uniform motion. This property of Newton's space time view was embodied by Galileo transformation.

That is,
$$\begin{cases} x'=x-vt \\ y'=y \\ z'=z \\ t'=t \end{cases}$$

The above transformation also indicates that, no time is nee-

ded in transmitting interaction between substances. Transmitting velocity of force equals infinity, which is what is commonly known as ultra-distance.

In a word, Space-time view in Newtonian mechanics eliminated the absoluteness of space point in Aristotelian space-time view—unequal rights of space-time points and absoluteness of time direction—one-way nature of time, but maintained the absoluteness of space-time interval.

Space-time absoluteness separated from substances led to the being of absolute coordinate system in Newtonian mechanics. The development of electromagnetism once urged the humans to seek for the being of ether, absolute coordinate system. While the negative result of Michelson—Morey experiment declared the failure of this attempt. Profound contradiction and conflict occurred between electromagnetism and Newtonian mechanics system, which forced people to think:

①To revise Newtonian mechanics space-time view, and explore new relativity of space-time;

②To deny objective laws of electromagnetism;

③To mend Newtonian mechanics mathematical formulation.

The objective laws of electromagnetism cannot be denied; it is not acceptable to mend Newtonian mechanics, for increasingly complex mathematical formulation becomes rather prohibitive. It appears that the first way was acceptable. Albert Einstein did choose such a road that it caused another important leap in human cognition of space-time.

Albert Einstein's relative space-time view.[19]

In theory of relativity, simultaneousness is relative.

Time absoluteness in Newtonian mechanics can be explained with absoluteness of "simultaneousness". So-called simultaneousness, it means that two things happen simultaneously (time interval is zero). For instance, one person in Wuhan gets up at six in

the morning, Beijing time, while another person in Guangzhou also gets up at six in the morning, Beijing time. Then it may be concluded that the two persons get up at six in the morning "simultaneously". Usually, it is believed that the concept of "simultaneousness" is absolute, whether regarding the earth—stationary coordinate system, or a spaceship—motional coordinate system. It indicates, in Newtonian mechanics, what happens "simultaneously" (time interval is zero) in a coordinate system may also happen "simultaneously" in any other coordinate systems; but, in fact, it is not completely correct. In the above example, the two persons get up "simultaneously" for the people on the earth in correct Beijing time; while for the observer in spaceship moving fast in space, he may find that the two persons do not get up simultaneously when "he observe this simultaneous" happening with his own clock. In theory of relativity, simultaneousness is relative, depending on which coordinate system we choose. In other words, time interval in theory of relativity is relative. When reference system is different, simultaneous events may happen at different time and non-simultaneous events may happen at the same time. Obviously, theory of relativity, compared with Newtonian mechanics, explored relativity of simultaneousness, or relativity of time interval.

In the theory of relativity, the concept of distance is also relative.

Albert Einstein's train—ground system is the typical ideal experiment in the interpretation of space relativity. Imagine there are two specific points "A" and "B" on the train in uniform motion. Given length "L" is measured on the train, how can we measure the distance between the two points on the ground? In Albert Einstein's method, when the train was rapidly moving along, two persons simultaneously photography the "A" and "B" points separately on the train and the ground at given moment, and measure the $A'B'$ length. In the theory of relativity, "simultaneousness" is rel-

ative and in relation with the choice of reference. Therefore, for different reference systems, to photography in their respective "simultaneousness" will obviously lead to different results. The length of an object has relation with the choice of its coordinate system. In two relatively uniform motion coordinate systems, person A finds person B's length shrinking in its moving direction and person B also finds person A's length doing the same. The dynamic and static lengths are not identical. Space-time view of theory of relativity further explored length relativity.

Time relativity and length relativity indicate that there is no absolute coordinate system in the world. Space-time and motion state of coordinate system are directly related; in coordinate system of different motion conditions, the results of time and space measurements are different; also, dynamic system and static system are neither simultaneous nor of the same length. In cognition of space-time, the humans have made a historical stride forward in eliminating absoluteness and promoting relativity.

Obviously, scientific space-time view has been developing on the way of eliminating absoluteness and promoting relativity.

In theory of relativity, Lorentz transformation reflects the above transformation of space-time features:

$$\begin{cases} x' = (x - vt)/\sqrt{1 - v^2/c^2} \\ y' = y \\ z' = z \\ t' = (t - vx/c^2)/\sqrt{1 - v^2/c^2} \end{cases}$$

Analysis showed that Lorentz transformation still left two aspects of invariance to relativistic space-time view, one being unique clock synchronization by light signals, and the other invariance of light speed. Any energy transmission speed cannot surpass light speed. Besides, in specific theory of relativity, "Vacant" space-time still exists and space-time remains the stage of motion and

change of substances. The influence of the motion of coordinate system without physical significance on space-time has left physicists and philosophers with doubts to ponder. How can space-time only be motion effect of coordinate system and have no relation with the motion of substance itself?

We will point out, in specific theory of relativity, intermediary information—light—used in observing the world is taken out in the transformation from reference system to coordinate system. In this transformation, changes of space-time image of substance caused by observation signals are also altered to the innate attributes of coordinate system. In general theory of relativity, space-time and the distribution of substances are connected, substantial distribution determines curvature degree of space-time. The curvature of space time is deformed near mass blocks. In curved space-time, substances tell space-time how to bend, while space-time tells substances how to move; vibration of mass block and change of space-time form gravitation wave. Light moves in curved space-time, and its speed direction is changeable. Compared with special theory of relativity, general theory of relativity eliminates the equality and the flatness of space-time and the invariance of the direction of light speed. It seems to be a stride towards understanding of relativity of space-time.

It is well known that space-time view of theory of relativity has brought great effects to the advance of science and technology, which should be attributed to the new discovery of relative features of space-time view of theory of relativity.

Space-time and modern physics.

For thousands of years, the main thread of human understanding of space-time is clearly visible, although views were divergent. In the debate between infinite and finite space-time views, it is beyond doubt that infinite viewpoint is more persuasive. However, the advantage of relative space-time is even more convincing

through the discussion of absolute space-time and relative space-time, and the birth of theory of relativity. God created space-time is mentioned no more in physics. Indeed, general theory of relativity, quantum field theory, the support of non-vacant space, all added to more doubts of the being of vacant space in nature. The human understanding of space-time is getting perfect, but the human cognition of space-time knows no bounds; with the development of physics, their cognition of space-time will become more penetrating and more deep-going. The human understanding of space-time is still developing.

All the natural appearances are discovered through observation, while in observation, the humans must make use of intermediary information. That is to say, any natural appearance is transmitted through intermediary information, without which we could not have observed any natural appearances. Naturally, intermediary information may not necessarily be visible light; it may be other wave range of electromagnetic wave as well. Furthermore, we may not use electromagnetic field to observe but other field information (say, gravitational field or so). So long as mutual interaction occurs, in principle, there should be an observational result, although not necessarily the same as that of electromagnetic field. Therefore, a natural corollary is: different observational information brings about different observational result; the theory from the observed result is related to observational information. Similarly, another simultaneous problem occurs: if the observational signal in Albert Einstein theory of relativity had not used light but some other signal, was the obtained space-time frame identical? Clearly, the human understanding of space-time is related to the property of medium field information of the motion condition of the observed objects. The appearance of space-time varies with different field information.

Of course, another problem arises: the observed result is re-

lated to the physiology of the observer. The observed results obtained by observers of different physiology are also different when they observe the same natural appearance. Man is only one common member of all universal beings while "natural world" is the totality of the observational result of "total beings" in the universe.

It may be put like this: the space-time we are familiar with is established with the help of light (or gravitational field) information and human physiology. If Man can use some other fields to observe substance motion in addition to the two mentioned above, or if he can absorb rational "reflects" of "other beings" on space-time, then the human beings will gain more understanding of the form of the substantial being in space-time.

Through the discussion in this chapter, we clearly see that, the human cognition of space-time has gone through a long history. First, Man mainly connected the property of "substances" with that of space-time, such as unequal rights of up and down in flat space-time, specific position of the earth core in spherical symmetry space-time, etc. Then, in Newton's space time, the property of "substances" with that of space-time was absolutely separated, which went to another extreme. "Substance" became a mass point, which possesses all physical property of "substance", and space-time was only the vacant stage for "substance" to play. Later, however, when it came to the theory of relativity, things reverted to the opposite direction. At the same time when relativity was continuously advanced, special theory of relativity linked space-time together with motion condition of "substance", while general theory of relativity connected the mass distribution of "substance" and gravitation with space-time. Thus, the property of "substance" and its space-time were too closely linked to be separated. Space-time is the extension of substance; no substance in the world is separated from space-time, or space-time from substance—this concept of materialist philosophy is further illustrated by science.

History will further prove that quantum mechanics will further push forward this reversion. In quantum mechanics, mass point is vacant inside atom but space-time is real, and matter wave does provide the description of this real space-time structure. Matter wave is curvature wave; substance and space-time are integrated. Substance shows itself with the structural form of "field".

Inside atoms, owing to electron transition, irradiation is discontinuous. It is understandable that space-time property provided by discontinuous effect of light is different from continuous effect of light in the macroscopic world.

2.3 Discussions of Space-Time Dynamics

2.3.1 Space-Time Dynamical Mechanism in Relativist Mechanics

So-called space-time dynamics indicates that space-time feature is related with interaction.

In general theory of relativity, it is not difficult to understand that space-time has dynamic mechanism, because general theory of relativity points out that space-time is curved and that space-time curvature is determined by gravitational field equation. One side of gravitational field equation is space-time curvature while the other side is momentum-energy tensor, space-time coordinate. The change of momentum must rely on force, so it may be said that, in general theory of relativity, the curvature of space-time is the result of force function. It is often said gravitational field enables space-time to turn curved, which we believe means the effect of space-time dymamics. In infinite distance, where there is no substance, momentum-energy tensor is zero. Without force action, space-time becomes uniform and straight. The property of space-time as the humans understand it is essentially determined by dy-

namic mechanism. Creation of universe—big bang theory, derived from general theory of relativity, assumed that the universe started from the explosion in the singularities, which is meant that the space-time came into being owing to dynamic mechanism. There must be force action in explosion, and universe was created with effects of explosive force. The study of spatiotemporal dynamical mechanism is bound to draw God-created universe back to the real world.

Generally, special theory of relativity is uniform and straight space-time, despite the effect of gravity on space-time, which we believe is only false impression. Provided that substantial mass increases with motional speed, gravity is bound to increase, and then, in special theory of relativity, gravitational change caused by mass effects would have profound intrinsic connection with spatiotemporal reality. However, in quantum mechanics, Louis de Broglie chauged the mass increase into the increase of the frequency of material wave.

As we all know, one of the direct results of special theory of relativity is relativistic effect of mass:

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}} \tag{2.1}$$

In equation (2.1), m_0 is mass when substance is static, and m is mass when substance is moving in speed v. Equation (2.1) indicates, mass changes with the motion of substance. Universal gravitation exists between masses. If we acknowledge the establishment of gravitational equation in space-time frame of the theory of relativity for the time being, then

$$f = G\frac{m_{10}m_2}{r^2} \tag{2.2}$$

In equation (2.2), m_{10} is the static mass of substance m_1, on which we establish coordinate system K. Then, K is static coordinate system. m_2 is dynamic mass of motional substance, when coor-

dinate system K′is established on m_2 ,K′is dynamic coordinate system. While

$$m_2 = \frac{m_{20}}{\sqrt{1-v^2/c^2}}$$

m_{20} is static mass of m_2 , v is the dynamic speed of m_2 in response to m_{10} ; in equation (2. 2), r is the distance between m_1 and m_2 ; given r, x, and x' coincide. Equation (2. 2) is universal gravitation formula observed in K system. Universal gravitation equation observed in system K′ is

$$f = G\frac{m_{20}m_1}{r^2} \tag{2. 3}$$

The difference between equations (2. 3) and (2. 2) is only the change of the observer's locations.

Given observer is at system K(on m_1), the ratio of universal gravitation after motion m_2 and before it (static) is:

$$\frac{f_{m_2}}{f_{m_{20}}} = \frac{1}{\sqrt{1-v^2/c^2}} \tag{2. 4}$$

In fact, this ratio has no relation with observer's location, because motion is relative; if the observer is at system K′(on m_2), the ratio of universal gravitation after motion m_2 and before it (static) also is:

$$\frac{f_{m_1}}{f_{m_{10}}} = \frac{1}{\sqrt{1-v^2/c^2}} \tag{2. 5}$$

Formulas (2. 4) and (2. 5) indicate that, after substance motion, universal gravitation are enhanced between m_1 and m_2 according to Lorentz contraction factor. Thus, space-time change before and after the motion of coordinate system K′ and the change of gravitational field are related. This change just occurs simultaneously in the unity of the whole space-time, and its enforced factor is Lorentz contraction factor. Obviously, space-time contraction can be regarded as the result of gravity enforcement. In special theory of relativity, theoretic system does not consider the curvature

of space time caused by gravity but implies space-time contraction given by gravity when the effect of observational signal is transferred into gravity enforcement. This contract goes on in the while space simultaneously as a global transformation, so it is still uniform and straight space-time, which is where the difference is between special theory of relativity and general theory of relativity in their establishment of mechanism. In special theory of relativity, the effect of gravitational field and Albert Einstein clock synchronization by light signals on space-time can be compared as follows:

(1) Given $v=0$, K, K′ system is relatively static, from the angle of clock synchronization by light signals, space-time contraction factor $\frac{1}{\sqrt{1-v^2/c^2}}=1$, K, K′ system has no difference in space-time: from the angle of gravitational field, between m_1 (K) and m_2 (K′), gravitational field is not changed $f=f_0$, system K, K′ is not changed in space-time.

(2) Given $v\neq 0$, K, K′ has relative motion, no matter observer is at system K or K′, from the angle of clock synchronization by light signals, space-time contraction factor $\frac{1}{\sqrt{1-v^2/c^2}}\neq 1$, simultaneousness in system K, K′ varies, space-time is different. From the angle of gravitational field, compared with motionless m_2 (K′), m_2 after motion, between m_{10} (K), m_2 (K′), the intensity of gravitational field in $\frac{1}{\sqrt{1-v^2/c^2}}$ factor's full space integration is enforced. The bigger v is, the bigger v/c, the bigger the change of field effect, and the bigger the space-time change; the smaller v is, the smaller v/c, the smaller the change of field function, and the smaller the space-time change. In fact, the human cognition of space-time was essentially obtained through interaction, and its distance is distinguished according to the intensity of the interaction. By the reference of the effect of the same field, if interaction

is strong, we say that the distance of the two points are near, and that if interaction is weak, the distance of the two points are far away. When the distance of the two points is measured according to the intensity of interaction, and if factors increase on certain condition (for example, motion m_2) according to $\frac{1}{\sqrt{1-v^2/c^2}}$, and interaction is compared with that when there is no such condition (for example, motionless m_2), it is felt that the two measured points gets closer according to $\frac{1}{\sqrt{1-v^2/c^2}}$ pattern. It explains the increase of force through the length of distance! It means measurement unit automatically increases in latter condition (equal in value to light moving in diagonal line to make measurement unit bigger. See appendix 1). The above measuring results and observer's coordinates is irrelevant. If the observer is in system K(m_1), he sees m_2 moving, so gravitational potential connected to m_2 increases, and space-time change observed is related to m_2 (space-time change on system K'); if the observer is in system K'(m_2), he sees m_1 moving in opposite direction, so gravitational potential connected to m_1 increases, and space-time change observed is related to m_1 (space-time change on system K). This is completely the same as the analysis result of Albert Einstein clock synchronization by light signals. In fact, $\frac{1}{\sqrt{1-v^2/c^2}}$ happens to be "equivalent weight" produced by the effects of electromagnetic force and gravity through space-time change, which further proves the inherent relation between space-time change of coordinate system connected to objects and the change of gravitational field around the objects.

(3) It should be pointed that, in special theory of relativity, Albert Einstein's analysis of space-time simultaneousness in clock synchronization by light signals is equal in value to our definition of measurement unit by intensity of effect of gravitational field. That

is because the intensity of clock synchronization by light signals and gravity effect has built a communicative bridge through theory of relativity of mass, indicating "clock synchronization by light signals" and "measurement of length in gravitational field" are equal in value in human experience, or the human beings would have been at a loss in their observation of the nature.

Now, we can analyze dynamic mechanism constructed in absolute space-time of Newtonian mechanics. Known by Lorentz transformation, space-time change mainly depends contracting factor $\frac{1}{\sqrt{1-v^2/c^2}}$, to be more exact, depending on ratio of v/c. When $v=0$, object m_2 is motionless, $v/c = 0$, filed effect does not change, space-time measurement of system K, K′ is the same. But when $v \neq 0$, in Newtonian mechanics, space-time records of system K,K′is also the same. Why? The reason lies in the application of ultra-distance effect in Newtonian mechanics. Ultra-distance effect, e. g. $c \to \infty$; now only if motional speeds of substance $v \neq \infty$, but $v=\infty$ is impossible, then $v/c \equiv 0$. It shows that, changes of field effect contribute nothing to space-time change, neglecting the influence of observational signal (or gravitational field change) on space-time. This is spatiotemporal dynamical mechanism in Newtonian mechanics, which is an extreme circumstance. Neglecting the influence of the change of field effect on space-time is the basic reason why Newtonian mechanics can get space-time independent of substance.

Special theory of relativity is different from Newtonian mechanics—its field signal in observation (light speed) is limited ($c \neq \infty$). In condition $v \neq 0$, limited signal speed lets $v/c \neq 0$ and space-time have contracting factor $\frac{1}{\sqrt{1-v^2/c^2}}$, so, the influence of the change of field effect caused by motion on space-time can be neglected, and system K, K′obtains different space-time measure-

ment. Spatiotemporal dynamical mechanism has produced substantial measure effects. So, from spatiotemporal dynamical mechanism, Newtonian mechanics is also the theory of extremity of relativist mechanism.

Relativist effects of mass indicate, in special theory of relativity, "gravity" is added simultaneously in the whole space (v = constant), object takes uniform motion, mass change has nothing to do with space location, but is similar to global transformation, thus space is still flat and straight; if mass change is interrelated with space location, object makes accelerating motion, "gravity" change is local $[v = v(x)、m = m(v(x))]$; similar to local transformation, space becomes not uniform, or frequency variation of material wave is related with its spacial location, and their essential difference lies there.

2.3.2 Space-time Features of Quantum Mechanics & Physical Significance of Wave Function Normalization

In normalization of wave function

$$\int_\tau c_n |\Phi_n|^2 d\tau = 1$$

Given

$$dv = |\Phi_n|^2 d\tau \tag{2.6}$$

If integral region also change from τ to V , normalization change to

$$c_n \int_V dv = 1 \tag{2.7}$$

So,

$$c_n \cdot V = 1$$

$$c_n = 1/V$$

Obviously, integral region V and integral region τ have different geometrical structures. Wave function normalization, in fact, is to change integral region τ into new integral region V with differ-

ent geometrical structure through wave function $|\Phi_n|^2$. To form normalization factor is to seek for volume ratio of differential element dv and integrated region V. This time, wave function normalization is

$$\int_V (1/V) dv = 1 \qquad (2.8)$$

In quantum mechanical curvature interpretation, Φ_n is "curvature" function, reflecting the change of space image of microscopic particle itself. The above normalization process, in fact, is the process to change the space feature of electron itself into new space feature of integrated region. To normalize is either to seek for volume ratio or to change space. When the space feature of electron itself is changed into pace feature of integrated region, it is Von Neumann phase space. Formula (2.6) demonstrates space transformation, reflecting space change of microscopic space-time and macroscopic space-time. The vibration of space structure is the characteristics of space time in quantum mechanics. Quantum field is space structure field, which describes wave particle duality of microscopic object through curvature vibration. To make Lorentz transformation on free variables (x, y, z, t) in space V, Erwin Schrödinger equation is transited to Paul A. M. Dirac equation. Vacuum feature in quantum field theory is space V feature.

Obviously, after wave function normalization, in microscopic world, the cognition of object "image" and motion law does not like observing single independent substance in vacant space as in macro world, but making judgment on particle "image" and motion law with space-time structure expressed by curvature. On different space-time points, the bending degree of curvature indicates corpuscular property, and curvature change shows undulatory property.

Penetrating analysis of the significance of the above wave function normalization enables us to better know why Erwin Schrödinger expressed mass density and electric charge with c_n ·

$m|\Phi_n|^2$ 、 $c_n \cdot q|\Phi_n|^2$. [20] With times m or q at two sides of formula (2. 8), we have:

$$\int_V (m/V)dv = m \tag{2.9}$$

$$\int_V (q/V)dv = q \tag{2.10}$$

In formulas (2. 9) and (2. 10), integrated function m/V , q/V can never more clearly express mass tendency m and electric charge q , only that, in this way, geometric structure of integrated region V is more complicated than τ. It may be difficult to draw its image manually, but with the help of a computer, the geometric feature of the integrated region—undulatory property—should be easily recognized.

We maintain that, the characteristic of space-time in human cognition is interrelated with the nature of observational signal used in observing the world. As for the nature of light, it is applied in Newtonian mechanic Euclid of Alexandria space-time. Light possesses the property of spreading speed infinite and isotropy, and Euclid of Alexandria space-time is continuous, uniform and isotropy, among which it can be regarded that $\hbar=0$, $c=\infty$.

In Hermann Minkowski space-time which is applied in special theory of relativity, light possesses the properties of speed finiteness and isotropy, and Euclid of Alexandria space-time is continuous, relative, uniform and isotropy, among which there is $\hbar=0$, but c= constant.

In Riemannian space of general theory of relativity, light possesses the properties of limited speed and bending and changeable directions, and space-time is continuous, bent and isotropy, in which, also $\hbar=0$, c=constant, but space is bent and light moves in oblique line.

The equations of Erwin Schrödinger and Paul A. M. Dirac are the products of the respective combination of quantum properties of light with space-time of Euclid of Alexandria and Hermann

Minkowski. While space-time of real quantum mechanics itself is Von Neumann configuration space, in which light property of the medium information to observe the world is $\hbar \neq 0, c = \infty$, or $\hbar \neq 0$, $c =$ constant. The combination of general theory of relativity with quantum mechanics is $\hbar \neq 0, c =$ constant, but space is bent and light moves in oblique line.

Light property is different; its theory structure is also different. Different theories have their premises of establishment and spheres of application, not to be confused or separated. Quantum mechanics is the theory summarized from experimental appearance; in turn, the experimental appearance will also prove the correctness of the theory, which is a closed logic loop. Energy quantization and the being of discontinuous effect ensure that all the experiments in testifying Bell's inequality based on local assumption will finally prove the correctness of quantum mechanics. So-called local and non-local dispute in EPR experiment is due to the fact that Albert Einstein and Niels Bohr did not consider the distinction of space-time features between continuous effect and non-continuous effect and spatial feature of wave function. Quantum entanglement also contains spatial entanglement.

In fact, in wave function probability interpretation, non-normalization wave function possesses no implication of probability, which is also called probability width. From above process, normalization is essentially to find volume ratio dv/V; the ratio value ought to have relation with curvature, as curvature function. From the very beginning, quantum mechanical curvature interpretation entrusts wave function with curvature implication. Wave function possesses dual properties of probability and curvature, and penetrates into the whole process of quantum mechanics interpretation, including quantum field theory, self-consistence of theory in logic structure, which has avoided logical contradiction in probability interpretation.

Reference

[1] Tao Delin, Li Deyang. Principles of Marxist Philosophy [M]. Wuhan: Wuhan University Press, 1999: 36-37.

[2] Zhao Guoqiu, Wang Ping. A Probe into Foundation of Modern Science of the Basic Theory of Traditional Chinese medicine [M]. Beijing: Science Press, 2005: 6, 124-127.

[3] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000: 160-165.

[4] Dong Guangbi. Contemporary New Daoism, [M]. Beijing: Huaxia Publishing House, 1991: 90-91.

[5] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000: 212.

[6] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000: 4.

[7] Zhao Guoqiu. Wonderful Thought [M]. Wuhan: Hubei People's Publishing House, 2000: 12-32.

[8] Liné De Vries. The Book of the Atom[M]. Translated by Lan Yishen. Nanjing: Jiangsu Science and Technology Press, 1982: 16.

[9] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000: 3.

[10] Zhao Guoqiu, Gui Qiquan. New Divine Comedy of Physics [M]. Wuhan: Wuhan Publishing House, 2004: 210-260.

[11] Jin Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000: 3.

[12] Xue Xiaodan, Zhang Hui. Modern Physical & Philosophical Issues [M]. Henan University Press, 1996: 80-151.

[13] Vladimir Lenin. Materialism and interpretation Criticism, Selected Works of Lenin, Vol. II [M], Beijing: People's Publishing House, 1995: 118.

[14] Vladimir Lenin. Selected Works of Lenin, [M]. Beijing: People's Publishing House, 1995:89.

[15] Zhao Guoqiu. Wonderful Thought [M]. Wuhan: Hubei People's Publishing House, 2000:170.

[16][17] Nicholas Copernicus. De Revolutionibus Orbium Coelestium[M]. Translated by Ye Shihui. Wuhan: Wuhan Publishing House, 1997:3-70.

[18] Lsaac Newton. Philosophiæ Naturalis Principia Mathematica [M]. Translated by Wang Kedi. Wuhan: Wuhan Publishing House, 1996:6-39、646.

[19] Albert Einstein. Meaning of Relativity [M]. Translated by Li Hao. Beijing: Science Press, 1979:16-70.

[20] M. Jammer. Philosophy of Quantum Mechanics [M]. Translated by Qin Kecheng. Beijing: Commercial Press, 1989:34-44.

第 二 章
物质观与科学时空观的演变

第一节 物质——外在世界的本原

什么是物质？物质——外在世界的本原。世界上千差万别，无限丰富的实物、客体、系统及其属性和关系的总和或统称。它在物理学哲学理论体系中，处在概念的最底层，是物理学家和唯物主义哲学家必须承认的第一哲学研究对象。

人类对物质的认识经历了漫长而艰辛的心路历程。

中国传统文化中"气"的概念，就包含有我们今天的物质概念。"气"的概念最早出现于西周末年，战国时期的荀子认为"气"是包含人在内的宇宙万物生成的共同基础。"天地合气，万物自生"，东汉王充这一认识，除了把"气"看成物质（东西）之外，还明显地包含有"气"（物质）的协调运动。"天地合气，万物自生"，天地之间"气"的协调运动，万物就自然地产生了。把"物"看成是一个由物质的运动和变化达到的稳定动态平衡形态，应该不会有什么大的歧义。因此，由"气"的"和合"而生成的"物"，当是一个稳定的动态平衡的"物质"系统。宋代的张载，明清之际的王夫之，他们都认为"气"是万物的本原，更对气作了一元论的发挥。中国的中医尤其看重"气"在人体中的作用，"气"无形无体，"气"的运行畅通是人体健康的基本保证。万物生于"气"，又复归于"气"。中国人的"气"一元论，通过"气"的演化（气化）提出了宇宙的一种生成模式。[1]

现代物理学中"场"的思想与中国古代"元气"自然观也是相通的。何祚庥院士就认为，"元气学说就是现代量子场论的滥觞"（《自

然辩证法通讯》1979(1):87)。

对于生命机体,赵国求认为,中医的“气”是生命物质的活力,由生命物质运动状态表征,一般对系统的稳定性作出贡献。活力由生命力决定。生命力是生命能、生命驱动力、生命潜力的总和。对系统稳定有益的物质运动状态和构成成分是好气;对系统稳定有害的物质运动状态和构成成分是坏气。阴阳是生命物质运动的状态参量。“气”流是人体内物质、能量、信息的流动和物质运动的转移。这就给“活力”赋予了科学的涵义,而非科学史上的神秘主义概念。如果把人体理解为一个相对稳定的动态平衡系统(最佳自稳态),那么,“气”将对生命的健康与稳定(阴阳平衡)起着决定性作用。对于非生命系统,“气”仍可以从“物质系统”的稳定性上作出定义。凡是对系统稳定性有益的物质运动状态及生成元素是“好气”,否则就是“邪气”。这与中国传统文化对“气”的理解是一致的。[2]

除“气”本原,中国传统文化中还有以老子“道”为中心的“道”本原。金吾伦认为,“道”比“气”更基本。“气”是“道”形而上向形而下落实的中间形态。[3]董光璧驳斥了“道”实的观点。“道”不是“构成实体”。[4]“道”“虚”,“道”“无形”,“道”“无”。由此金吾伦将老子“道”的思想概括成以下五点:①道是宇宙万物的始祖,万物由道而生。②道生万物不借助外力,不靠“第一推动”,而是靠自身的力量,“道法自然”。③道虚,无形体。④道生万物是一个过程。道的本质是运动和变化。⑤说明生和长的关系,自生自长,一切自然。董光璧、金吾伦据此总结出中国传统文化中的“生成论”思想,并认为“生成论”在东方是主流。

物质作为构成(或生成)世界万物的本原,从哲学意义上讲,很难说它具有具体的形态。物质是无限丰富的实物、客体、系统及其属性和关系的总和。从这个意义上去认识,“道”是物质一切运动形态和规律的总和与“道虚”、“道无形”、“道法自然”没有认识上的矛盾。

道的本性是运动和变化,“道法自然”。由道而生的万物自生自长,不借外力。这正是运动是物质的固有属性的本质概括。

“天下万物生于有,有生于无”,这就是人们常说的“无中生有”。老子的“无”不是空无一物。“道虚”、“道无形”也不应理解为“道”空无一物。“虚和无形”是和“有”之后的“实物”相对应的概念。从哲学

上讲,“无”是相对于“有”之前的状态,“有”是相对于“无”之后的状态。“无中生有”关键在于生,在于相互作用。“无中生有”,是把“虚”变为“实”的过程,把“无形”变为“有形”的过程。“无中生有”是物质的一种运动变化过程,是“物”生的过程。这里有中国传统哲学中的科学内涵。

结合本书提出的相互作用建构实在论,我们认为康德的“自在之物”与我们提出的“自在实体”与“无”属同类概念,而康德的“现象”或我们分离出的“现象实体”与“有”属同类概念。“无中生有”则对应“自在实体”向“现象实体”的转化。此外“现象实体”具有建构特征,“现象实体”之外我们仍然保留有“现象”概念。相互作用建构实在论是结构实在论中的一种版本,与相互作用生成论也容易沟通。

金吾伦还提出“金妖是生成妖”。[5]我认为“道生一,一生二,二生三,三生万物”中的“三”才是“金妖”。万物直接的生成原因是“三”。道是决定整体一的,一是指混沌的宇宙整体,二是宇宙生成之后内部阴阳两极的矛盾运动,三是“合气”,也就是形成稳定系统所需的物质和相对于稳定平衡态的物质运动形态。“物”是物质的运动和变化达到的相对稳定的动态平衡系统。“金妖”与拉普拉斯妖结合而有因果决定性,与麦克斯韦妖结合而有随机性,与哈肯妖结合而有自组织性。“金妖”是决定实物以什么方式“显现”于世的更加深层的物质动因。

中国的古人除了“气”本原、“道”本原之外,还提出了构成万物的是金、木、水、火、土等五种基本元素的思想。周幽王时代的史伯认为,金、木、水、火、土是五种基本的物质元素,它们的相互配合,就形成各种物体,这就是“和实生物”。[6]但这种朴素的物质构成论在后来五行与阴阳的结合中,逐渐失去了它的物质结构的原始本意,变成了万物之间矛盾运动的符号载体,物质构成论思想没有得到坚持。当然,还有“道虚”、“道无形”和“气无形”的影响,中国人最终没有沿着物质结构的还原论思维方式走下去,这是东西方科学文化传统产生差异的重要根源。[7]

在西方,古希腊哲学家亚里士多德就认为,万物由水、火、土、气四种元素组成。元素是永恒的,“物”则是这些元素的聚合与分散,元素之间没有虚空,游移着一种不可名状的第五种物质。[8]与亚里士多

德同时代的德谟克利特则认为，万物的本原是原子和虚空。“原子是不可再分割的东西，它们在虚空中运动。物质产生与毁灭就是原子在虚空中的结合和分离的结果。原子和元素一样只有空间性，而无时间性”。[9]说得通俗一点，就是“原子”和“元素”是突然就有的，它无需时间的演化就存在于世界，而且万古不变。原子和元素的这一特性，实际上就是古代的“量子”，只是那时古人没有“量子”这个概念而已。万物由不变的元素或原子聚合与分散构成，董光璧、金吾伦称其为西方的“构成论”。他们认为西方构成论是主流。目前，一切寻求构成世界的最基本粒子的努力，都是世界起源于“只有空间性，而无时间性”这一思维方式的延续。消除基本粒子这一突变属性的最佳模型就是微观粒子的波粒二象性模型，微观粒子的内禀波动性，将时间过程延伸到粒子内部，时间的渐变有了模型依托，正好消除了“只有空间性，而无时间性”的认识断层。量子力学曲率解释正是把空间和时间的起点，放在了同一个起始点上，用曲率模型取代点粒子模型。物质波是曲率波，曲率的大小表示粒子性，曲率的变化表示波动性。微观客体的波粒二象性，在量子力学曲率解释中有了和谐的统一。[10]

德谟克利特的原子论在与亚里士多德的元素论争论中，原子论难于被当时的人们所理解，所接受，灰积尘封了近一千九百年。然而近现代西方科学的飞速发展，无疑是原子论取得的辉煌胜利。在原子论发展成熟的过程中，伽桑狄、伽利略、培根、牛顿、道尔顿都对原子论的发展作出过重大贡献。元素论和原子论在理论的发展中，最后获得了统一的说明，人们发现元素乃同种原子的总称。[11]现在发现，连同人工制造的元素共有一百多种，而原子则不计其数。

生成论与构成论的相同与差异在于：无论是生成论还是构成论，“物”亦或“系统”都需要“生成”或“构成”元素，“物”在生成或构成过程中都有物质的运动和变化，生成或构成的“物”——“物”之间性质是可以千变万化的。这是共同点。但东方的生成论，其元素在“物”（系统）里或“物”外性质是不同的，有变化的，“物”里的元素不能等同于“物”外的元素；而构成论，其元素在“物”里或“物”外性质是相同的，不变的，“物”里的元素等同于“物”外的元素；此外，生成论中整体和部分的关系也有了新的理解等等。整体大于部分之和，元素的叠

加将突现出新的性质。这是生成论与构成论的本质差异。生成论更多地强调了物质的运动和变化，强调了相互联系，包括生成“物”（或系统）的元素自身。

赵国求认为，整体可以还原为部分，但“物”里（系统里）的元素（子系统）与分离出“物”外的元素有重要的质的差异。这是系统突现新性质的重要原因。它将为量子力学和中医提供重要的认识论基础。

“场”也是一种运动着的物质。

“场”最先是法拉第为描述电的相互作用和磁的相互作用而引入的一个辅助形象概念。描述电的相互作用时，法拉第用一些“力线”来表述电力的作用性质。这些“力线”的性质就是法拉第的“电场”性质。对于磁力作用，法拉第同样也以“力线”的特性来表示，并称之为磁场。后来场的概念又用来描述其他的物理现象。如温度在物体内部的分布。人们把物体内部的温度分布描述为坐标和时间函数。流体的速度分布也可以描述为速度“场”。这里“场”是一个描述某种物理规律在物质内部分布的数学函数。“场”离不开物质，但“场”本身不是“物质”。当时人们认为“场”纯粹是一种描述物质内部物理规律的数学手段。

把“场”看成是物质的一种表现形式是麦克斯韦电磁理论诞生以后的事。麦克斯韦从理论上证明了电磁场的存在，赫兹从实验上确证了电磁场的存在。起先，人们也认为电磁场像温度场和速度场一样要借助于媒质来传播，而这种媒质就是以太。物质在“以太”中运动，既无阻力，也无相对滑动。人们用各种实验来检验“以太”的性质并证明它的存在，但最终以迈克尔逊—莫雷实验否定了“以太”的存在。最后人们只好承认电磁场本身就是物质，它的传播不需要任何媒质。

当电磁场与量子力学结合以后，人们对电磁场的物质性有了更深刻的理解。1905 年，爱因斯坦首次证明了光的量子性——即光是由光量子组成的。光是一种电磁场，电磁场本身是物质也就确定无疑了。自然界中还有强相互作用场（胶子场），弱相互作用场（中间玻色子场），引力场（引力子场）。这些场都是物质，今天已无人怀疑了，只是引力场的引力子至今人们还没有发现。

场物质都有其运动速度。电磁场的传播速度是 3×10^8 m/s。引

力场当今人们也认为是以光速传播的,胶子场、中间玻色子场也假定以光速运动。“场”是一种运动着的物质是无疑的。

玻色子场有一个很重要的特性,即它的使命是传递物质之间的相互作用。电磁场传递电磁作用,引力场传递引力作用,强相互作用由胶子场传递,弱相互作用由中间色子场传递。没有这些场物质的“存在”,物质间的相互作用就不可能实现。“场”物质运动的有限速度表明,物质间的相互作用是以有限速度传播的。

在量子场论中,费米子用费米子场描述,传递相互作用的玻色子用玻色子场描述。基态量子场(真空)有零点振动,量子场受激变成激发态,量子场退激发射相应的微观粒子。量子场仍然是物质的运动或运动着的物质的新形式。[12]

物质世界是处于永恒的运动之中的。物质是运动的唯一主体,世界上既没有不运动的物质,也没有无物质的运动。

现代场论的出现,无疑对亚里士多德的“非虚空世界”提供了有力的证据。但无论是古代朴素的原子论及其虚空世界,还是现代科学的物质结构观——物质由分子组成,分子由原子组成,原子由原子核、电子组成,原子核由质子、中子组成,质子、中子由夸克组成,如此等等;也无论是古代朴素的元素论及其非虚空世界,还是现代的基本粒子、量子场论、引力场论等,都是试图从物质世界自身去寻求世界的本原,承认物质世界的存在不依赖于人的主观意识而存在。这种思维路线是合理的,正是这种合理性,带来了今天科学技术的飞速发展。然而,原子论也好,元素论也好,基本粒子、场论也好,这些都不是唯物主义哲学认识的物质的全部,它们都只能是物质在某种相互作用(自然力)中,在一定认识层次上的具体体现。现在有的物理学家正在致力于把万物归结为某一种(比如超弦)或几种元物质的研究(比如基本粒子),这仍然是关于物质在某种或几种自然力作用下物质结构的研究,不管将来的研究是证实还是证伪“元物质”的存在,都不能改变唯物主义哲学对物质的基本理解。

德国古典哲学家康德对不依赖于人的主观意识而独立存在的外在世界做了著名的哲学论述。康德认为,我们所知觉到的世界上一切事物都是事物的现象,而事物的本来面目,即事物的“本体”——“自在之物”,则是我们的感官所感知不到的,只能用我们的理智或思

维才能猜测到它。在康德看来，事物的“本体”是不可知的，可知的是它的“现象”——“自在之物”所“现”之“象”，也就是事物作用于我们的感官时给我们产生的表象。康德认为“本体”虽然不可知，但“本体”的存在是无可置疑的，如果没有“本体”，就不可能在我们的感官产生关于它们的表象。

现代科学研究还表明，人类还可以用理论结构建构“自在之物”之象，我们称其为“现象实体”。

承认“本体”的存在，是康德哲学的唯物主义成分，不过，把事物的本来面目推到完全不可知的彼岸却是不能接受的。有些事物今日不可知，明天可能就成为可知；今日认识不全面，由于科学技术的发展，明日可能会认识得更多、更具体。“本体”的庐山真面目，会在认识的不断深化中得到澄清和揭露。我们每个人都在经历“自在之物”向现象、“为我之物”的简单明白的转化。[13]

我们反对康德的不可知之论，并不等于我们赞成人所认识的世界就是世界的全部。人作为自然的一员，在长期的生存进化中，人对世界的感知，在生理结构上有些是属于进化了的，有些是属于退化了的。或许当我们还是类人猿的时候，能够感知到的世界外在之物，由于“野性”的消失，现在却可能感知不到了；更有甚者，有些外在之物却可能属于生理结构本身从来就无法感知到的。这种外在之物从根本意义上讲，从来就被人的生理结构和生理功能衰减了。宇宙的暗物质可能就是其中的一种。认识了物质世界的这一层，它将告诉人们，在新的认识矛盾出现时，不要茫然失措，可能有新的暂不为人所感知的东西存在于世界。此外，人无法感知，一方面，不等于此物不存在于人的意识之外；另一方面，不等于其他“另类”就完全无法感知。存在于人的意识之外的这个外在之物（物质），应该是宇宙间所有生物（包括可能的外星人）感知的总和。人只是认识外在世界秘密的普通一员，没有什么绝对的优势地位。当然，现有事实表明，我们人类认识的世界，可能比其他“另类”认识的世界更加全面。人还可以借助“另类”的认识补充自己的认识！这是人类聊以自慰的一面。

此外，世界本身就具有层次性。宇观、宏观、微观都各有其不同的作用机制和运动规律，在本体向现象、现象实体的转化中，与“各类生物”自身的生理结构及观察使用的中介传媒的属性也有重要的关

系。用人的一个层面的经验知识及由此形成的逻辑结构去统领物质世界的各个层次，去追索世界的本原，构造世界的起源，显然具有片面性，必然给人类自身带来认识上的困惑。在本书的研究中，我们将着重向世人展示这一点。

物质存在于意识之外，标志一种客观实在。这种客观实在是人通过感觉感知的，为我们的感觉所复写、摄影、反映。[14]人如何通过感觉复写、摄影、反映“自在之物”？这涉及到思维的物质本性问题。一百年前要人们从物理学、化学、生物学、脑科学及神经科学上去认识人脑的这一反映机理是要求过高了。但20世纪末，脑科学和神经科学研究的飞速发展，对揭示思维的物质本质都提供了重要的科学依据。物质不依赖于意识而独立存在，而意识（思维）却不能脱离物质。思维作为动词，体现为脑神经物质的运动过程；作为名词，体现为脑神经物质的运动形式；思维的内容则育于脑物质的运动过程和运动形式之中。对神经电流的研究表明，思维至少是与电磁场的物质结构形式相对应的。人类已经通过思维的电磁场物质属性，做到了成功的远距离控制。[15]现代科学重大研究成果表明，物质不仅存在于意识之外，而且能被意识所复写、摄影、反映。意识不是先天自生的东西，而是被物质所决定的，意识对物质的复写、摄影、反映都具有现代科学的生物、生理、化学、物理学机理。就这一意义讲，物质既在意识之外，也在意识之中。世界统一在物质之中。这就是我们从本体论上所坚持的唯物主义物质一元论。法国哲学家笛卡尔将物质、思维二分，提出意识与物质彼此独立，互不依赖的二元论，在现代科学成果面前，将不攻自破，自动进入历史博物馆，只能作为人类的文化遗产供众人欣赏了。思维与物质的对立，是把“思维的内容（结果）”等同于“思维”造成的，其局限性是显而易见的。至于思维（意识）决定物质的唯心主义世界观，那就更不值得一提了。种种迹象表明，当代的唯心主义者为了挽救自身衰亡的命运，正在向科学求援，将神学贴上科学的标签。宗教神学乞求科学的认证与说明，就是一个重要的事例。

第二节 科学时空观的历史演进及其特点

人类对时空的科学认识经历了漫长的历史演变过程。归纳起来可分为四个历史阶段:①远古平面(直觉经验)时空观;②古代球对称时空观;③牛顿绝对时空观;④爱因斯坦相对性时空观。从历史的角度看,时空观的科学演进,无论在前科学时期和科学时期都伴随着两个重要特点,一是减少并消除绝对性;二是挖掘并提升相对性。历史证明,时空认识的每一次科学革命都要带来科学技术的巨大进步,20世纪爱因斯坦对时空认识的新飞跃,对科学技术进步的贡献尤为巨大。在某种意义上说,时空认识的大变革是物理学和科学技术大变革的前提和基本标志。因此,寻求对时空的科学认识有着十分巨大的积极意义。

远古平面(直觉经验)时空观。[16]

人类对自然的认识总是从自己的切身经验开始的。在远古时代人类的活动范围很小,生产力低下,更谈不上什么科学技术,只知道上有天,下有地,平平的地面向四周延伸,大地是平直的概念也就从经验中产生了。一个容器,最切身的体验是居住的房间,上有顶,下有地,四周有壁,于是又构成了头脑中的上下四周的"空间"概念。高山从平地升起,地窖在平地以下,可见空间是可以上下延伸的。在房间里或天地间,我们既可以向前走,也可以向后走,既可以向左走,也可以向右走。也就是说平面上的方向是相对的,哪一个方向都是可以随意运动,无限延伸的,但上下的方向却有些特殊。高处的东西可以下落,直至掉进井底,而井底的东西却不能反"掉"上来,因此"空间"的上下是不可颠倒的。

我们的古人还对平面空间作了进一步的想像。他们想像平直的大地安置在一个龟背上,而龟则漂浮在大海中,地震则是海龟摄动的结果。因为空间有上下之分,经验中平面翻过面物体就都掉下去了,因此,只要龟一翻身人类全都会掉进无底的深渊之中。头顶为上,脚底为下,把平直的地面抽掉,一切就无止境地掉下去。空间的上下是不平权的,上与下是绝对的,只有两个绝对相反的方向。

为了比较空间的大小,古人需要创造空间的测量方法。起先古

人由于没有公认的标准长度作单位，所以测量的结果是很不一致的。在古代，有些部落甚至用首领的脚长作单位，有些则又用臂长作单位，首领换了单位也就不同。相同的物体测量的结果不一样引起了不少的混乱。后来长度单位逐渐统一了。在中国，这项伟大工程是由秦始皇完成的。从此，相同的物体也就有了相同的测量结果。在致力于消除测量混乱中，古人是基于一个最基本的概念的，这就是客观物体的长度是固定不变的，要不，统一单位就没有意义了。

这是人类对空间概念认识的第一个历程。

一切自然现象都在运动和变化之中，“过程”的流逝是一切自然现象和人类活动的基本特征。盘古开天地，耶稣创世，都代表记时的开始。人类从“过程”的流逝中又抽象出了时间概念。我们的古人很早就注意到，一切周期变化的过程都可以用来作为时间的测量单位。古人观察到的最简单的周期变化有日出日落，月圆月缺，有四季的周期变化。于是测量时间的计时单位——日、月、年也就产生了。也许古人从泉水滴漏中得到了启示，于是古人又创造了滴漏计时器，时间的计时单位一下子缩短到了一滴水滴下的过程，这就有点接近今天的分与秒了。在古人眼中，“钟”是相同的，测量结果也应一样，否则“钟”的发明就没有意义了。古人对事物具体“过程”的长短也认为是固定不变的，或者用今天的话说，古人在日常经验中看不出“时间”与物体“运动状态”有什么联系。

古人对时间的认识还有另一个重要特点，那就是时间的单向性。人死了不能复生，这表明事物在发展演变中，其过程都是不可逆反的。过程的不可逆，带来了时间认识上的单向性。时间的发展方向总是从过去流向未来的。

空间的上下不等价，时间的前后不等价，长度、时间间隔的不变性，这就是我们所说的人类远古平面(直觉经验)时空观。

古代球对称时空观。[17]

两千多年前亚里士多德和托勒密建立了“地球中心说”。他们认为宇宙是有限的球体，圆形的地球静止地居于中心；日、月、星辰都围绕着地球运转；月亮、太阳、行星和恒星分别处在不同的球壳上；它们都做完美的圆周运动。在亚里士多德的理论体系中，人类生活的大地不是平板式的，而是圆球形的。这是时空观的第一次大革命。人

类生活的大地不是平面，而是球面，在球体上，上与下的概念就变得不是绝对而是相对的了。在球体的一边认为是朝上的方向，而在球体的另一边则被看作是向下的方向了。反过来也一样。上与下的空间概念，一下子由唯一的180°的直线方向转而变成了360°的任意方向！怎么能想像，人类生活的广阔地面一下子变成了一个没有严格上下方向的球面呢？这显然是与人的直接经验相违背的。两千多年前的亚里士多德，敢于冲破古人对平面空间的看法，主张地球是一个球形，对宇宙给予了统一的解释，宣布经验只能在局部范围内适用，这是很了不起的。可以想见，树立球形的地球观念是需要克服相当大的成见所带来的阻力的。上与下是相对的，空间的各个方向是等价的，没有哪一个方向具有特别的优越性，这就是空间方向的相对性。空间方向由绝对到相对，人类在认识时空上朝科学时空观迈出了关键的一步。

亚里士多德空间虽然方向是相对的，但空间的不同点却有着不同的特性。这与平面时空观有相通之处。亚里士多德球面时空观仍然保留着空间位置的绝对性。在地球中心说中，物体在宇宙中的位置具有关键的作用。地球的球心就是宇宙的中心，每个物体在运动中只要没有阻挡，都力图达到各自的天然位置。物体之所以运动是因为它们没有达到自己的天然位置。地球附近的物体天然位置是地球的球心。亚里士多德说这是落体运动的真正原因。这样，在亚里士多德的时空观里，地球球心的位置就是非常特殊的。在支配万物运动的自然规律中，这个点具有决定性的作用。这就是空间点的绝对性。这样亚里士多德空间虽然具有各向同性的性质，但空间各点的位置并不等价。

亚里士多德的理论基本上是一个定性的理论，几乎没有定量的物理定律，因此理论对时间的理解并没有什么新的突破，时间仍是过程流逝的伴随物，一切过程的时间测量也与坐标系的选取无关，时间是绝对的，而且具有单向性。

总之与远古平面时空观相比，亚氏时空观消除了空间方向上的绝对性，而保留了其他绝对性。

牛顿绝对时空观。[18]

批判亚里士多德的地球中心说，在今天即使是中学生也并不难

办到。然而，16 世纪以前在西方，亚里士多德时空观却统治了近一千九百年之久，在把亚氏学说奉为圣明的一千九百年间，科学一直止步不前，亚里士多德的学说成了科学进步的严重障碍。到了 16 世纪，哥白尼创立了“日心说”，认为太阳居于行星系的中心，地球和其他行星绕着太阳运转，“地心说”从此开始动摇。此后，布鲁诺、伽利略、牛顿又为“地动说”奋斗了许多年，布鲁诺甚至为此献出了宝贵的生命。以哥白尼——伽利略——牛顿为代表的新科学，否定了地球中心的特殊地位。牛顿的引力定律

$$f = G\frac{m_1 m_2}{r^2}$$

表明，苹果可以落到地球上，照样可以落到月球上，苹果落地和月亮绕地球运行是同一个原因引起的。地球的球心同月球的球心一样，在空间不断地变动着位置。伽利略则更明确地指出，物理定律的形式与相互匀速运动的坐标系的选择无关。因而牛顿力学中没有地球的中心地位，任何空间点都是平权的。相对于任何时空点来计算，物理规律都是一样的，空间被看作脱离物质并且供万物表演的舞台。牛顿力学时空观消除了时空点的不平权性。然而，时空点平权了，但却带来了时空的绝对均匀、平直性。不过，这个绝对性在广义相对论中得到了消除。

像抽象空间一样，牛顿把时间也从物质演变过程中抽象出来，变成既脱离空间，也脱离物质的任意流逝的客观物。在牛顿第二定律中

$$m\frac{d^2x}{dt^2} = F$$

给定初始条件，我们既可知道物体的现在，又可以知道物体的未来，还可以知道物体的过去。时间没有起点，于是时间的单向性也由相对性取代了。不过我们要注意，牛顿力学的时间可逆性，并不意味着牛顿力学体系中人可以死而复生，而是意味着时间的前后是无穷的，既可流向未来也可流向过去。时间的流向在牛顿第二定律中是可逆的。这就是时间流向的相对性。

牛顿力学的时空观与亚里士多德时空观相比，虽然减少了绝对性，提升了相对性，但同样也还保留有绝对性。牛顿说：“绝对空间，

就其本性来说，与任何外在的情况无关，始终保持着相似和不变。”“绝对的，纯粹的数学时间，就其本身和本性来说，均匀地流逝而与任何外在的情况无关。”空间可以脱离物质的运动，时间也可以脱离物质的运动，空间与时间也无关系，因此，时空舞台中的空间距离和时间间隔都是绝对的。用今天大家熟悉的话说，即长度和时间与坐标系的选择无关，物理定律在相对匀速运动的坐标系中形式不变。牛顿时空观的这一性质在数学上由伽利略变换来体现。

即
$$\begin{cases} x' = x - vt \\ y' = y \\ z' = z \\ t' = t \end{cases}$$

上述变换还表明，物体间的相互作用不需要传播时间。力的传播速度等于无穷大，这就是通常所说的超距作用。

总之，牛顿力学时空观，消除了亚氏时空观空间点的绝对性——时空点的不平权性和时间方向的绝对性——时间的单向性，而保留着时空间隔的绝对性。

脱离物质的时空抽象导致了牛顿力学体系中绝对坐标系的存在。电磁学的发展，又促使人类一度努力寻求绝对坐标系——以太的存在。然而这种努力终于以迈克尔逊——莫雷实验的否定结果而宣告失败。电磁学与牛顿力学体系发生了深刻的矛盾冲突。电磁学与牛顿力学的冲突迫使人们思考：

①修改牛顿力学的时空观，挖掘时空中新的相对性；

②否认电磁学的客观规律性；

③修补牛顿力学的数学表述。

电磁学的客观规律不容否认，修补牛顿力学的数学表述也不可取，因为越来越复杂的数学表述形式令人望而却步。看来只能选择第一种思路方式。爱因斯坦正是选择了这样一条道路，引起了人类认识时空的又一次重大飞跃。

爱因斯坦相对性时空观。[19]

相对论中同时性是相对的。

牛顿力学中的时间绝对性可以用“同时性”的绝对性来加以说明。所谓同时，就是两事件同时发生(时间间隔为零)之意。比如，某

甲在武汉于北京时间早晨六点钟起床，某乙在广州也是北京时间早晨六点钟起床，那么我们立即得出结论，甲乙两人“同时”于早晨六点钟起床。通常我们总是认为“同时”这个概念是绝对的，不管对静止的坐标系地球，还是对运动的坐标系宇宙飞船都是如此。这表明，在牛顿力学中对一个坐标系“同时”发生（时间间隔为零）的事件，对其他任何坐标系也都“同时”发生。其实这个习惯并不完全正确。上述两人“同时”起床这件事，对于地球上对准了钟的北京时间来说是同时的，但对于宇宙中高速运动的飞船上的观察者，用它的钟来观察这个“同时”发生的事件却发现，这两个人并不同时起床。相对论中同时性是相对的，它决定于选用哪一个参考系，或者说相对论中时间间隔是相对的。当参考系变化时，同时的事件可能变得不同时，不同时的事件可能变得同时。可见，相对论与牛顿力学相比，又挖掘出了一个同时性的相对性，或者说又挖掘出了一个时间间隔的相对性。

相对论中距离概念也是相对的。

说明距离相对性的典型理想实验系统是爱因斯坦火车——地面系统。设想匀速运动的火车上有两个特定点 A'、B'，若在火车上测量的长度为 L'，如何在地面上测量这两点间的距离呢？爱因斯坦的办法是在火车飞速驰过时，地球上和火车上由甲乙两人在给定时刻分别对 $A'B'$ 同时拍照，测量 $A'B'$ 的长度。由于相对论中“同时”性是相对的，与参照系的选择有关，因此，对不同参照系来说，要按照各自的“同时”进行拍照，这样导致的结果显然是不会相同的。物体的长度与坐标系的选择有关。两个相对匀速运动的坐标系，甲看乙的长度在运动方向上收缩了，乙看甲的长度也在运动方向上收缩了，动系和静系的长度不相等。相对论时空观又挖掘了一个长度的相对性。

时间的相对性与长度的相对性表明，世界上没有绝对坐标系存在，时空与坐标系的运动状态是直接相关的，不同运动状态的坐标系中时间和空间测量结果不相同，动系与静系不同时也不同长。人类在认识时空上，又朝消除绝对性，提升相对性的总方向上迈出了历史性的一步。

可见科学时空观，是在减少并消除绝对性，挖掘并提升相对性中前进的。

相对论中，反映上述时空特性的变换是洛仑兹变换：

$$\begin{cases} x' = (x - vt)/\sqrt{1 - v^2/c^2} \\ y' = y \\ z' = z \\ t' = (t - vx/c^2)/\sqrt{1 - v^2/c^2} \end{cases}$$

分析表明，洛仑兹变换仍然给相对论时空观留下了两个不变性：其一是光信号对时的唯一性，其二是光速不变性。任何能量的传递速度都不能超过光速。此外，在狭义相对论中，“空”的时空仍然存在着，时空仍是物质运动变化的舞台。没有物理意义的坐标系的运动对时空的影响，给物理学家和哲学家留下了思索的疑点。时空难道只是坐标系的运动效应而与物质本身的运动没有关系？

我们将要指出，狭义相对论中观察世界所用的中介信息——光，是在参照系到坐标系的转换中抽掉的。观察信号引起的物体时空形象的变化也在这种转换中变成了坐标系的固有属性。在广义相对论中时空与物质的分布有了联系，物质的分布状况决定了时空的弯曲程度。质量块附近，时空弯曲变形。在弯曲时空中，物质告诉时空如何弯曲，时空告诉物质如何运动，质量块振动，时空变化，形成引力波。光在弯曲的时空中运动，速度的方向也是可变的。与狭义相对论相比，广义相对论消除了时空的均匀、平直性和光速度方向的不变性，这似乎又朝挖掘时空认识中的相对性迈进了一步。

相对论时空观给科学技术进步带来的巨大效应是众所周知的，这应归功于相对论时空观中相对性的新发现。

时空与现代物理。

人类对时空的认识几千年来尽管众说纷纭，但主流脉络却是清晰可见的。在无限时空与有限时空的争论中，无疑无限时空好像更有说服力。而绝对时空与相对时空的讨论，物理学中相对论的诞生，使人们更加确信相对时空的优越性；神创时空在物理学中不可能有人再旧调重弹；广义相对论、量子场论，对非虚空的支持，诚然使人类对自然界中虚空的存在增加了更多的怀疑。人类对时空的认识在逐渐完善，但人类对时空的认识并没有穷尽，物理学的发展使人类对时空的认识将更加深入、深刻。人类对时空的认识还在发展中。

自然界中的一切现象都是通过观察发现的，而观察必须引进观

察使用的中介信息。这就是说任何自然现象都是通过中介信息传递的,没有中介作用信息,我们不可能观察任何自然现象。当然中介作用信息不一定是可见光,它也可以是电磁波的其他波段。进一步,我们不用电磁场去观察,而用其他的场信息去观察(引力场或别的什么场),只要彼此能发生相互作用,原则上也应有观察结果,但不一定与电磁场的观察结果相同。因此一个自然的推论是:不同的观察信息,有不同的观察结果,根据观察结果建立的理论,与观察信息相关。同样,又一个很自然的问题产生了,如果爱因斯坦相对论中的观察信号,不用光,而用别的什么信号,所得的时空框架还相同吗?显然,人类对时空的认识与观察物体运动状态的中介场信息的属性相关。场信息不同,时空的表现也各异。

当然,还有一个很自然的问题,就是观察结果与观察者的生理结构相关。不同生理结构的观察者,观察同一个自然现象所得的结果,也是不同的。人只是宇宙生物的普通一员,"自然界"是宇宙中"全部生物"观察结果的总和。

是否可以这样说,我们今天习惯了的时空,是借助于光(或引力场)信息及人的生理结构建立起来的,如果人类一旦能用上述两种场以外的别的什么场来观察物体的运动,或者吸收"另类"生物对时空的合理"反映",那么人类对时空中物质存在形式的认识将可能有新的变化。

实际上通过本节的讨论我们清晰地看到,人类在认识时空的历史长河中,先是把"物"的属性更多地与时空的属性联系到一起,例如平面时空的上下不等价,球对称时空的地球球心的特殊地位等等。到了牛顿时空,"物"的属性与时空的属性绝对分离了。这是一个极端。"物"变成了质点,具有"物"的一切物理属性,时空只是"物"的表演的空洞舞台。但是到了相对论,事情又朝相反的方向复归。在相对性不断提升的同时,狭义相对论将时空与"物"的运动状态联系到一起,广义相对论又把"物"的质量分布及引力与时空联系到一起,"物"的属性与"物"的时空变得密不可分。时空是物质的广延性,世界上既没有脱离时空的物质,也没有脱离物质的时空的唯物主义哲学观念进一步得到了科学的说明。历史将会进一步说明,量子力学将进一步推动这种复归。量子力学中,原子内部,质点是虚的,时空

是实的，物质波正是对这种实时空结构的描述。物质波是曲率波，物质与时空融为一体。物质以“场”的结构形式表现在时空中。

原子内部，由于电子跃迁，发光是不连续的，由光的非连续作用提供的时空特性与宏观世界光的连续作用不同，应是很好理解的。

第三节　时空动力学讨论

一、相对论力学中的时空动力学机制

所谓时空动力学是指时空特性与相互作用相关。

广义相对论中时空具有动力学机制很好理解，因为广义相对论指出时空是弯曲的，并且时空曲率由引力场方程决定。引力场方程的一边是时空曲率，而另一边则是动量一能量张量，它是时空的函数。动量的变化必须有力的出现，因此可以说广义相对论中的时空弯曲是由于力的作用的结果。我们认为，人们常说引力场使时空变得弯曲了，就是讲的时空动力学效应。在无穷远处，没有物质的地方，动量一能量张量为零，没有力的作用，时空就变得均匀平直了。人类认识的时空，其性质，本质上是由动力学机制决定的。由广义相对论派生的宇宙创生说——大爆炸理论，说宇宙始于奇点处的爆炸，这也告诉人们，时空的产生具有动力学机制。爆炸必有力的作用，宇宙就是在爆炸力的作用下创生的。时空动力学机制研究将把宇宙从神创论中引回到现实世界。

一般认为狭义相对论是均匀平直时空，属运动学效应，不考虑引力对时空的影响。我们认为这只是假象。如果考虑物体质量随运动速度的增加，必然造成引力的增加，那么狭义相对论中的质量效应引起的引力变化，就与时空的相对性有深刻的内在联系。而量子力学中，德布罗意则把这种质量的增加变成了物质波频的增加。引力被“消解”了。

众所周知，狭义相对论的直接结果之一是质量的相对论效应：

$$m=\frac{m_0}{\sqrt{1-v^2/c^2}} \tag{2.1}$$

(2.1)式中 m_0 是物体静止时的质量，m 是物体以速度 v 运动时

的质量。(2.1)式表明,质量随物体的运动速度而改变。质量之间是有万有引力的,这里姑且承认狭义相对论时空框架中万有引力公式还成立,那么应有

$$f = G\frac{m_{10}m_2}{r^2} \tag{2.2}$$

(2.2)式中 m_{10} 是物体 m_1 的静止质量,我们把坐标系 K 就建于 m_1 上,K 即为静止坐标系。m_2 是运动物体的动质量,并且把坐标系 K′建于 m_2 上,K′即为运动坐标系。而

$$m_2 = \frac{m_{20}}{\sqrt{1-v^2/c^2}}$$

m_{20} 是 m_2 的静止质量,v 为 m_2 相对于 m_{10} 的运动速度,(2.2)式中的 r 为 m_1、m_2 之间的距离,且选 r、x、x' 三者重合。(2.2)式是在 K 系中观察到的万有引力公式。在 K′系中观察到的万有引力公式是

$$f = G\frac{m_{20}m_1}{r^2} \tag{2.3}$$

(2.3)式与(2.2)式的区别只是观察者地位的变化。

现在设观察者在 K 系(站在 m_1 上),做 m_2 运动后与运动前(静止时)万有引力的比值:

$$\frac{f_{m_2}}{f_{m_{20}}} = \frac{1}{\sqrt{1-v^2/c^2}} \tag{2.4}$$

这个比值实际上与观察者地位无关,因为运动是相对的,如果观察者在 K′系(站在 m_2 上),做 m_1 运动后与运动前(静止时)万有引力的比,其值同样是:

$$\frac{f_{m_1}}{f_{m_{10}}} = \frac{1}{\sqrt{1-v^2/c^2}} \tag{2.5}$$

(2.4)式和(2.5)式表明,物体运动后 m_1、m_2 之间的万有引力按洛仑兹收缩因子增强。因此,坐标系 K′运动前后时空的变化与引力场的变化发生了联系。这个变化刚好是在整个时空中统一同时产生的,并且其增强的因子就是洛仑兹收缩因子。可见,时空的收缩可认为是引力的增强造成的。狭义相对论中,理论体系没有考虑引力造成的时空弯曲,却隐含了观察信号作用转换成引力增加由引力给出

的时空收缩。这个收缩是全空间同时进行的，是一种整体变换，因此它仍是均匀平直时空。这是狭义相对论与广义相对论时空建立机制的区别所在。狭义相对论中引力场对时空的影响，与爱因斯坦光信号对时对时空的影响，可作如下比较：

①如果 $v=0$，K、K′系相对静止，从光信号对时的角度看，时空收缩因子 $\frac{1}{\sqrt{1-v^2/c^2}}=1$，K、K′系时空无区别：从引力场角度看，$m_1$（K）、$m_2$（K′）之间引力场没有变化 $f=f_0$，K、K′系时空无变化。

②如果 $v\neq 0$，K、K′有相对运动，不管观察者在 K 系还是在 K′系，从光信号对时的角度看，时空收缩因子 $\frac{1}{\sqrt{1-v^2/c^2}}\neq 1$，K、K′系内同时性不同，时空有区别。从引力场的角度看，与 m_2（K′）不运动相比，m_2 运动后，m_1（K）、m_2（K′）之间引力场的强度按 $\frac{1}{\sqrt{1-v^2/c^2}}$ 因子全空间统一增加了。v 越大，v/c 也越大，场的作用变化越大，引起的时空变化越大；v 越小，v/c 也越小，场的作用变化越小，引起的时空变化也越小。应该说，人类对时空的认识本质上是通过相互作用提供的，是按相互作用的大小来判别距离的远近的。用同一种场的作用作参照，相互作用强，我们就说两点距离近，相互作用弱，我们就说相互距离远。当按相互作用的大小来测定两点间的距离时，如果相互作用在某种条件（如 m_2 运动）下按 $\frac{1}{\sqrt{1-v^2/c^2}}$ 因子增加，与不存在这种条件（如 m_2 不动）时相比，则感觉到被测的两点按 $\frac{1}{\sqrt{1-v^2/c^2}}$ 方式趋近了。这是通过距离的远近来解释力的增加！这相当于在后一种情况下测量单位自动变大了（等价于光走斜线使测量单位变大，见附录 1）。上述测量结果与观察者在哪个坐标系无关。观察者在 K 系（m_1），则看到的是 m_2 的运动，因此是与 m_2 联系的引力势增加了，观察者看到的时空变化与 m_2 有联系（时空变化在 K′系上）；观察者在 K′系（m_2），则看到的是 m_1 朝相反的方向运动，因此，是与 m_1 联系的引力势增加了，观察者看到的时空变化与 m_1 有联系（时空变化在 K 系上）。这与爱因斯坦光信号对时分析的

结果完全一样。实际上 $\frac{1}{\sqrt{1-v^2/c^2}}$ 恰好是电磁力作用与引力作用通过时空的变化引出的“当量”。它进一步证明了与物体联系的坐标系的时空变化与物体周围引力场的变化之间的内在联系。

③应该指出，狭义相对论中爱因斯坦用光信号对时，对时空同时性的分析，与我们用引力场作用的大小定义测长单位是等价的。因为光信号对时与引力作用的强弱，通过质量的相对论效应架起了沟通的桥梁。这表明“光信号对时”与“引力场测长”在人类经验生活中等价，否则人类在对大自然的观察中将会莫衷一是。

现在我们可以分析牛顿力学中绝对时空建立的动力学机制问题。由洛仑兹变换可知，时空的变化主要取决于收缩因子 $\frac{1}{\sqrt{1-v^2/c^2}}$，更确切地说取决于 v/c 的比值。当 $v=0$ 时，物体 m_2 不动，$v/c=0$，场的作用不变，K、K′系的时空量度相同。但是当 $v\neq 0$ 时，牛顿力学中 K、K′系的时空记录还是一样。为什么？原因在于牛顿力学中用了超距作用信号。超距作用，即 $c\to\infty$，此时只要物体的运动速度 $v\neq\infty$，而 $v=\infty$ 是不可能的，则 $v/c\equiv 0$。这表明，场的作用的变化对时空变化的贡献为零，忽略了观察信号（或引力场变化）作用对时空的影响。这就是牛顿力学中的时空动力学机制。它是一种极限情形。场的作用的变化对时空的影响忽略不计，是牛顿力学可以把时空独立于物体之外的根本原因。

狭义相对论与牛顿力学不同，观察物体的场信号——光的速度有限（$c\neq\infty$）。在 $v\neq 0$ 的情况下，有限的信号速度使得 $v/c\neq 0$，使时空有了收缩因子 $\frac{1}{\sqrt{1-v^2/c^2}}$，因此，运动引起的场的作用的变化对时空的影响不可忽略，K、K′系有了不同的时空量度。时空动力学机制发生了实质性的计量效应。所以从时空动力学机制看，牛顿力学也是相对论力学的极限理论。

质量的相对论效应表明，狭义相对论中“引力”是全空间同时增加的（$v=$常数），物体做匀速运动，质量的变化与空间位置无关，类似于整体变换，因而空间仍然是平直的；若质量的变化与空间的位置相关，物体做加速运动，“引力”的变化则是局域的［$v=v(x)$、$m=$

$m(v(x))$]，类似于局域变换，空间变得不均匀，或者说物质波的频率变化与空间位置相关。这是两者的根本区别。

二、量子力学中的时空特征及波函数归一化的物理意义

在波函数归一化数学形式

$$\int_{\tau} c_n |\Phi_n|^2 d\tau = 1$$

中，令

$$dv = |\Phi_n|^2 d\tau \tag{2.6}$$

积分区域也由 τ 变换到 V，则归一化形式变为

$$c_n \int_V dv = 1 \tag{2.7}$$

于是

$$c_n \cdot V = 1$$

$$c_n = 1/V$$

显然积分区域 V 与积分区域 τ 有不同的几何结构。波函数的归一化，实际上是将积分区域 τ 通过波函数 $|\Phi_n|^2$ 变换成新的不同几何结构的积分区域 V。配制归一化系数就是寻求微元体积 dv 与被积分区域 V 的体积比。此时波函数归一化形式变为

$$\int_V (1/V) dv = 1 \tag{2.8}$$

在量子力学曲率解释中，Φ_n 是“曲率”函数，反映微观粒子自身空间形象的变化。上述归一化过程，实际上是将电子自身的空间特性变成新的被积分区域空间特性的过程。归一化既是寻求体积比，也是空间变换。当把电子自身的空间特性转换成被积分区域的空间特性之后，这就是冯·诺依曼的相空间。(2.6)式表明的空间变换，体现微观时空与宏观时空空间的变换关系。空间结构的波动是量子力学的时空特征。量子场就是空间结构场，它通过曲率的波动，描述微观客体的波粒二象性。对 V 空间中的自由变量(x,y,z,t)作洛仑兹变换，薛定谔方程就过渡到狄拉克方程。量子场论中的真空特性是 V 空间的特性。

显然，波函数归一化之后，在微观世界，对客体“形”和运动规律的认识，已不能像宏观世界那样在虚空中去观察单个独立的实体，而

只能用曲率表示的空间结构来对粒子的“形象”和运动规律作出判断。在不同的时空点上，曲率的大小表示粒子性，曲率的变化表示波动性。

深入分析上述波函数的归一化意义，更能体现薛定谔用 $c_n \cdot m|\Phi_n|^2$、$c_n \cdot q|\Phi_n|^2$ 表示质量密度和电荷密度的物理意义。[20]将(2.8)两边同乘以 m 或 q，有：

$$\int_V (m/V)dv = m \tag{2.9}$$

$$\int_V (q/V)dv = q \tag{2.10}$$

(2.9)式和(2.10)式中被积函数 m/V、q/V 表示质量 m 和电荷 q 的体密度是再清晰不过的了，只是这时的被积区域 V 的几何结构比 τ 复杂得多。用手描绘出它的图像也许是很困难的，但借助于计算机，被积分区域的几何特性——波动性应该说是很容易看出的。

我们主张，人类认识的时空特征与人类观察世界使用的观察信号的性质相关。就光的性质而言，适用于牛顿力学的欧氏时空，光具有传播速度无限和各向同性的性质，欧氏时空是连续的、均匀的、各向同性的，其中可以认为 $\hbar=0, c=\infty$。

适用于狭义相对论的闵氏时空，光具有速度有限和各向同性的性质，闵氏时空是连续的、相对的、均匀的、各向同性的，其中还有 $\hbar=0$，但 $c=$常数。

适用于广义相对论的黎曼空间，光具有速度有限和方向弯曲可变的性质，时空是连续的弯曲的、各向异性的，其中也是 $\hbar=0, c=$常数，但空间弯曲光走斜线。

薛定谔方程和狄拉克方程是各自把光的量子特性和欧氏时空、闵氏时空结合的产物。而真正的量子力学自身的时空是冯·诺依曼的组态空间。其中观察世界的中介信息光的特性是 $\hbar\neq0, c=\infty$，或者 $\hbar\neq0, c=$常数。而广义相对论与量子力学的结合则是 $\hbar\neq0, c=$常数，但空间弯曲光走曲线。

光的性质不同，理论结构不同，不同的理论有自己建立的前提条件和适用范围，我们既不能混淆，也不能割裂。量子力学是从实验现象归纳总结出来的理论，反过来实验现象也会证明理论的正确性，这

是一个闭合的逻辑循环。能量量子化及非连续作用的存在，使得验证基于局域假设的贝尔不等式的所有实验，最终将只能证明量子力学的正确性。EPR实验中的所谓局域非局域的争论，原因就在于爱因斯坦和玻尔均未考虑连续作用与非连续作用时空特性的区分及波函数的空间属性。量子纠缠就包含有空间的纠缠，是曲率波的纠缠。

其实，在波函数概率解释中，未归一化波函数并没有概率含义，人们叫它概率幅。从上述归一化求解过程看，归一化实际就是寻求体积比 dv/V，这个比值应该与曲率相关，是曲率的函数。量子力学曲率解释从一开始就赋予波函数曲率含义，波函数具有概率和曲率双重属性，并贯穿到量子力学解释的全过程，包括量子场论，理论在逻辑结构上前后自洽，这就避免了概率解释中的逻辑矛盾。

参考文献

[1] 陶德麟，黎德扬. 马克思主义哲学原理[M]. 武汉：武汉大学出版社，1999：36-37.

[2] 赵国求，王平. 中医基础理论现代科学基础初探[M]. 北京：科学出版社，2005：6，124-127.

[3] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：160-165.

[4] 董光璧. 当代新道家[M]. 北京：华夏出版社，1991：90-91.

[5] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：212.

[6] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：4.

[7] 赵国求. 奇妙的思维[M]. 武汉：湖北人民出版社，2000：12-32.

[8] 利纳·德弗里斯. 原子科学的两千四百年[M]. 兰宜申，译. 南京：江苏科学技术出版社，1982：16.

[9] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：3.

[10] 赵国求，桂起权. 物理学的新神曲——量子力学曲率解释[M]. 武汉出版社，2004：210-260.

[11] 金吾伦. 生成哲学[M]. 石家庄：河北大学出版社，2000：3.

[12] 薛晓舟，张会. 现代物理学哲学问题[M]. 开封：河南大学出版社，1996：80-151.

[13] 列宁. 列宁选集. 第二卷[M]. 北京:人民出版社 1995:118.
[14] 列宁. 列宁选集. 第二卷[M]. 北京:人民出版社,1995:89.
[15] 赵国求. 奇妙的思维[M]. 武汉:湖北人民出版社,2000:170.
[16][17]尼古拉·哥白尼. 天体运行论[M]. 叶式辉,译. 武汉:武汉出版社,1997:3-70.
[18] 伊·牛顿. 自然哲学之数学原理宇宙体系[M]. 王克迪,译. 武汉出版社,1996:6-39,646.
[19] A. 爱因斯坦. 相对论的意义[M]. 李灏,译. 北京:科学出版社,1979:16-70.
[20] M. 雅默. 量子力学的哲学[M]. 秦克诚,译. 北京:商务印书馆,1989:34-44.

Chapter 3
Principles of Interaction

3.1 General and Special Principles of Interaction

Principles of interaction include general principle of interaction and specific principle of interaction.

3.1.1 General Principle of Interaction

General principle of interaction explains general connection of objects. In philosophy, it refers to the relation of all objects and phenomena, and the interaction, inter-influence, inter-condition of internal elements of objects and phenomena. External connection is the relation of the interaction, inter-influence and inter-condition between one object, phenomenon, or its process and the other object, phenomenon, or its process; internal connection refers to the relation of the interaction, inter-influence and inter-condition in object, phenomenon, and internal elements of its processes.

General connection of things is objective, universal, and diverse. The objectivity indicates this connection is not human imagination but the inherent nature of an object, the objective existence independent of people's will. Connection can be discovered but not created. The universality reveals that, in the world, all objects, phenomena and the interior and exterior of their processes are interrelated, no "objects that are not interrelated"; the whole world

is an interrelated whole. There are no isolated, static, or unrelated objects. "Noumenon is its own cause." (Benedictus Spinoza) Each object displays the universality of connection through itself, and also demonstrates its own existence and reality through the universality of the connection. The natural world behaves in this way, so does the human society. The diversity is related with extensiveness of the world and infinity of development. The main forms of the connection of objects include: cause-effect connection, positive connection and occasional connection, natural connection and non-natural connection. Cause-effect connection is intrinsic essential connection that one appearance is bound to cause another, including the chronological sequence. Positive connection is the inherent formulation of the existence and development of the objects, which formulates the basic tendency of the development of objects, and which is determined by the inner contradiction of the objects. Occasional connection indicates accidental happening of objects. Such is occasional connection that substance may appear or may not appear; or it may appear in this way or in that way. Materialists believe that, the occasional connection of objects is external formulation of the existence and development of the objects, determined by external conditions or inner non-fundamental contradiction of objects. Natural connection is the basic connection reflecting original feature of objects, which determines the essential property of objects. Non-natural connection illustrates outward characteristic and external connection of objects, expressing false appearance of objects. Real appearance is the direct essential appearance of objects, while false appearance is the distorted appearance of the nature of objects. As often happens, real appearance of an object is likely to be covered by its false appearance; real appearance and false one is both objective. The opinion violates dialects that false appearance has no relation with its innate character. Though false, the false appearance still expresses the special form of essential aspects of

objects. Objective phenomenon is bound to connect with its nature, and the nature is the law of the development of objects. The law is natural connection while phenomenon is non-natural connection.

The specific forms of universal connection of objects also include: direct connection and indirect connection, internal connection and external connection, the main connection and minor connection and so on.

It is the basic principle of materialists to see through the appearance to the essence in studying nature and human society.

All things in the world are universally connected, and universal connection contains interaction; "Interaction is the real ultimate cause."[1] It is evident that, no matter in the natural world or human society, any objects show their existence in their interrelation and interaction. There are no isolated, static, non-interrelated and non-interacted objects in the world.

3.1.2 Special Principle of Interaction

Different from conventional representation theory, special interaction principle illustrates how the known natural appearances are formed and emphasizes the complex scientific process of cognition. It reveals the relation between Man and Nature.

3.1.2.1 Several related concepts and their interconnections

①Substances

Substances are the essence of the external world, also the foundation of all things. In philosophy, substances are absolute, with no conception of form and structure. In physics, atoms, electrons and elementary particle, even quark, superstring, etc. cannot be equally regarded as philosophic principles, but the reflection of substance principle in physics.

②Substance-in-itself (noumenon)

Substance-in-itself is object independent of human consciousness. "substance-in-itself" is not something unknown, and the

"moon" is a case in point. "The moon exists all the same whether we look at it or not." However, through observation, "moon" is transformed into "lunar sphere"—"thing-for-us". [2] There is nothing which is unknown in the world: what is unknown in the past may become known at present. This transformation is cognition.

Substance corresponds to "existence", and "substance-in-itself" to "reality".

Compared with "substance", "substance-in-itself" has made a big stride in the formation of "image". And it comes with the concept of "body"; as to how this "body" is formed, philosophers have not further studied it. Where there is substance there is interaction, and substance and interaction supplement each other, without any problems in which is the first or which is the second. From the universal metaphysical concept of "interaction", interaction should be the cause of the formation of "body". Interaction makes substance into noumenon, and presents itself as the "kink" of certain relation. Although interaction may reflect the exchange of certain substance (boson), the human will not know what noumenon is like if they do not observe it, but they can know it, because interaction is still a universal abstract concept here. Because there is "body", or in Locke's words "material substance" [3], "noumenon" is "reality" in the theory of noumenon, which is closer to the real world than "being". However, if noumenon does not function with the observational signal that the humans used (for example, light), its image and reality will not be perceived by the human beings. Therefore, together with Locke's concept, we call noumenon as "substance-in-itself". Compared with the concept of substances, "noumenon" has been "condensed" to "body" through the interaction of "natural force", "but what these 'bodies' may probably like is not known to us." [4]

"Existence" is distinguished from "reality" in this book. "Existence" is different from "reality", for when we talk about "reality" we

are emphasizing interaction. In concept, "existence" and "substance" correspond, while "reality" corresponds to "noumenon" and "physical substance".

③Physical substance

Physical substance, though this concept cannot be found in existing philosophy dictionaries, is widely used by physicists and physics philosophers. It indicates research object that physics theory refers to. [5] According to classical physics, classified from their substantial states, physical substances have gas state, liquid state and solid state. Gas state has no image or structure (no definite volume); liquid state has no image but structure (with certain structure); solid state has image and structure. Classified from structure, physical substances include molecules, atoms, atomic nucleus, electrons, protons, and neutrons, some of whose "images" we know, but some we do not know. Take electrons in atoms for example, we have no idea of their "images". Analytical reductionists believe that, microscopic objects such as atoms and electrons possess invariable properties inside and outside the system. For instance, electrons in atom and electrons separated from atom are identical in their properties.

Compared with noumenon, physical substance reflects effects of four natural forces (gravity, electromagnetic force, weak interaction force and strong interaction force) on the formation of "body". With different natural forces, the research object which is studied in physical theory—conduct of physical substance—is also different. They are distinguished by quality carrier (m), charge carrier (q), weak-charge carrier (g), strong-charge carrier (G).

In Newtonian mechanics, relativistic mechanics, and existing quantum mechanics, physical substances are abstracted to mass point, their "images" being neglected. Mass point is a substance without "size" but with "physical content". The research objects which are indicated by physical theory—conduct of physical sub-

stance—are all physical realities.

④Substance of appearance

Substance of appearance is opposite to noumenon. No such concept is in existing philosophy dictionary. According to prevailing philosophic concept, "appearance" indicates sensible presentation caused by "substance-in-itself" (noumenon) functioning on human sense organs. It reflects external, scattered and changeable aspects; "substances" is usually referred to as the objects that exist independently as the basis of all properties and principle of all things on earth. Substance, related to appearance, is noumenon on which appearance depends. Appearance and substance together form new concept, which hears somewhat contradicted: what is appearance is not substance, and what is substance is not appearance. Then, what is meant by "substance of appearance", which is either appearance or substance? Appearance is sensible presentation caused by "noumenon" functioning on human sense organs. This sensible presentation is external, scattered, and changeable, sometimes possessing image and structure, sometimes not. It is either connected with "noumenon" or medium information and distinctive visual ability. Appearance and substance are put together to construct "substance of appearance", which chiefly emphasizes the stable "image" of "object" in sensible presentation, and also stresses the objective cognition process with either "appearance" and "image" and "body". "Substance of appearance" is systematic and stable sensible presentation caused by comprehensive function of human organs (or their extension) and cerebral nervous system, as "noumenon" functions through observational signals. It indicates there is a scientific substance functioning process in human cognition of the objective world. Sensible presentation is a kind of biological construction by human brain. "Substance of appearance" is a concrete reflection of noumenon under specific conditions, which is objective reality although it is related with the property of medi-

um received by human brain and human cerebral structure. When substance of appearance is used as physical research object, it becomes physical substance. The introduction of the concept of substance of appearance will have great help for our comprehension of researched objects indicated by quantum mechanics.

The proposition of "substance of appearance" is a complement of scientific cognitive process and improvement of representation theory, which was impossible in Immanuel Kant.

"Irreductive pattern" is a wrong conclusion of Thomas Kuhn when he mistook "substance of appearance" as "substance-in-itself".

⑤Observational signal

Observational signal is detective signal used by the humans in understanding the world. Without observational signal, man would not know what "noumenon" is, nor would they know the functions and laws of the four basic "natural forces". The property of observational signal directly affects human observing and measuring results of "noumenon", including the characteristics of space time of "substance of appearance". Therefore, once "substance of appearance" is involved, man as the subjective effect is added. In the concepts like "object" and "appearance", there are human subject effects. "Observational medium signal" is the necessary objective foundation to perceive presentation in human cognition of the world.

Observational signal corresponds to human experience. The space-time the humans know is bound to be impressed with the characteristics of space time of "substance of appearance". Thus, the philosophic ideology that space is the extensive substance gains physical foundation.

⑥"Reduction of substance of appearance to noumenon" refers to the effects of neglecting observational signal effect in the process of human cognition of the world, including neglecting the effects on the characteristics of space time of noumenon. So, the characteristics of space time of "substance of appearance" can be regarded as

the characteristics of space time of noumenon. We will prove that Newtonian mechanics is similar to such mechanics.

⑦Transformation of "noumenon" into "substance of appearance" refers to acknowledging the effects of observational signal on human cognition of the world, and on the characteristics of space time of noumenon, either.

⑧Fundamental interaction generally refers to universal natural force. Through observation, present human beings begin to know the four fundamental interactions: gravity, electromagnetic force, strong interaction force and weak interaction force.

⑨Value and significance: It is believed that, without Man, all things in the natural world would be of no value and significance. The value and significance of "substance of appearance" is meaningful only to the humans, which is similar to F. W. Nietzsche's viewpoint.

⑩Multiple sign "·": expresses the interdependent relation of "*appearance*" and "significance" in semantic interpretation; while in syntax, its visual significance is arithmetical. If "group theory" is proved (that is, bring rule system of general arithmetic operation into syntax), new prediction will appear (See basic logic equation 3-1). The logic levels of the above concepts are shown in diagram 3-1, "Appearance" is generally referred as the characteristics of space time of appearance and substance of appearance.

In daily life, people usually neglect the perceiving process from noumenon to substance of appearance through observational signal, but directly from interaction of "natural force" to substance of appearance. As a result, substance is often thought of as noumenon.

The advocates for truth of scientific reality mistook substance of appearance as noumenon, and denied the difference between noumenon and substance of appearance, while the empiricists of scientific anti-reality only noticed the appearance but omitted noumenon. The former neglected the effects of observational signal on

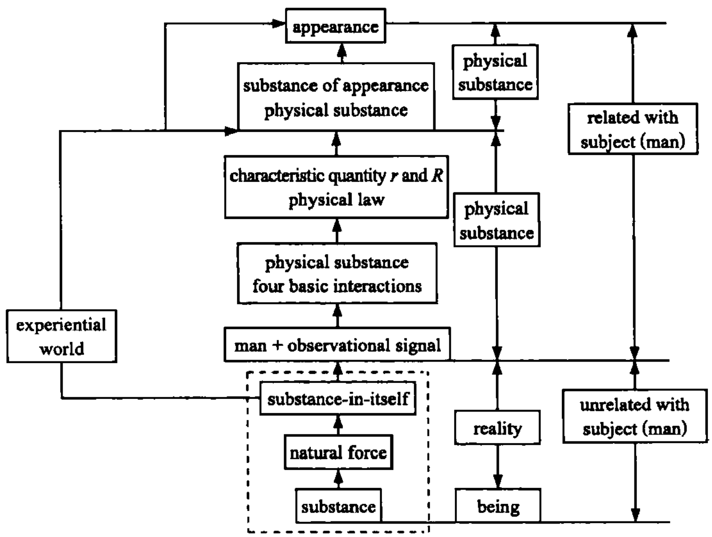


Figure 3-1 Logic levels of human cognition of the world

noumenon reflected in space-time, and the latter forgot that if there is no object for observational signal to act on, it is impossible for appearance to emerge. Obviously both are of one-sidedness. Our aim is to establish an integrated theory that keeps the correct parts and omits the shortcomings of the both parties, thus dialectically reconstructing modern physics prospect of Immanuel Kant critical philosophy.

In natural world, there are two kinds of elementary particles, e. g. fermions and bosons, the latter being particle that passes interaction. Fundamental interaction is realized in the exchange of bosons. Different from abstract relations, fundamental interaction still reflects the exchange of substances; equally, different from abstract relational reality, substance is primacy in interactive construction reality.

Fundamental interaction is realized through exchanging bosons, which is an expression of substances. Light is boson, passing electromagnetic interaction. In the relation between man and the

nature, human cognition process of reality is the process of substance action. If the process of interaction of substances is drawn and changed into abstract relation, just because this abstraction, relation reality starts from the logic initial point of "nihility", thus philosophical foundation is laid that quantum object is untraceable.

Interaction is the foundation on which relation is established, but it is not equal to relation. Interactive reality and relational reality not only have connections but also more important difference. In the theory of relational reality, it is believed that relation is primacy, thus by accident substance primacy is cast off (the core of materialist epistemology), for noumenon behind appearance and substance of appearance is cast off, which cuts the ground on which materialist epistemology stands. In the theory of interaction constructional reality, the transition of special interaction principle to general interaction principle is not the transition of substance primacy to relation primacy but noumenon to substance of appearance. In our opinion, relational reality in fact refers to the reality property of substance of appearance, not that relational reality contains interactive reality but that relation only stays on the cognitional lever of substance of appearance. Substance of appearance is open, and the openness of relative reality reflects that of substance of appearance. Relational reality is the product of one-sided stress on experience relation.

3.1.2.2 Special interaction principle and objective space-time image

In the natural world, images of all objects in space-time, from cosmic planets to atoms and electrons in the microscopic world, are formed by interaction between substances. The properties of interaction between substances are different: properties of gravity, electromagnetic force, strong interaction force and weak interaction force are different; interaction properties and volumes are different; space-time image of objects formed through interaction is also different. As for molecules, atoms, electrons that form the earth,

protons and neutrons that form atomic nucleus, and quark that forms protons and neutrons, owning to the difference of their interaction properties and volumes, the images and motional states of the objects they have formed in space-time are also different, reflecting the difference of "state equation" and "solutions" that describe them. The earth is spherical, moving around the sun; what forms the image and motional state of the earth is long-distance gravity. Without gravity, the earth's space-time image and motion law would not be formed. The earth's radius r and spherical curvature $R(R = 1/r)$ thus formed characterizes the earth's image property in space-time under the effects of gravity. The earth's orbit around the sun may reflect the state of the earth moving around the sun, and the equation that determines orbit movement is called the state equation of the earth movement. Corresponding to this, we name r as characteristic radius of the objects in space-time, and R as characteristic surface curvature that connects with objects; r and R characterize substance's own space-time image while the solution of state equation characterizes specific state of substance movement.

Fundamental interactive forces in the natural world are called in a joint name "natural force". Their existence has no relation with the human existence. "Noumenon" is the "image" of substance formed in fundamental interaction. Also, when the nature of interaction is different, "image" is different; it is something independent of "human" consciousness: if the humans do not observe it, it is unknown, but it still exists.

However, the natural appearance, as we know it, and all the natural laws summarized from it, still rely on the observational signals man uses. When interactions on "objects" are different, observational signals are different; generally, their images expressed in space-time are different, including its basic physical volume r and R that describes "body" and variation of movement equation. Not being measured, any images (appearance) are unknown. The images

and laws of motion of objects in space-time are related with the feature of observational signals.

Under the action of natural force, the moon has its own image and motional state in the sky, whether we see it or not makes no difference. However, without observational signal light, or if we do not observe it at all, we would not know the moon's image and the laws of its motion. In a rather simple and direct comprehension, it would be typical anti-reality viewpoint to say "the moon does not exist when we do not look at it", because, according to reality, no one can definitely say that noumenon does not exist. So, the correct opinion is "the moon would not exist as a lunar sphere when we do not look at it", or "the moon still exists when no one looks at it". [6] We believe that the moon, as substance of appearance, has space-time image, but if the humans do not observe it as noumenon, they would never know its image! This will not lead to agnosticism, because only "substance of appearance" has practical significance to the human beings; man can understand it by transforming "noumenon" into "substance of appearance". In a word, the appearance (or substance of appearance) we observed is synthetic products of noumenon produced by the action of fundamental natural force and observational signals. Without the aid of observational signals, people would not know what noumenon is. To put it in the angle of philosophy, the relations of "noumenon", "substance of appearance" and "appearance" can neither be directly mixed up, nor separated. In "substance of appearance" contains a scientific cognition process.

Therefore, we sum up the complete narration of special interaction principle as follows:

In natural world, space-time images and states of all objects are formed from the interaction of substances, including both the action of fundamental natural force and the function of observational signals the humans used in observing the world. The change of in-

teraction is bound to accompany the change of theoretical structure.

To carry out particular analysis on the stress of objects, it is found that stress can be classified into internal and external forces. In ordinary circumstances, when internal force is equal to zero, substances cannot get condensed. Without condensation, certain materials that form "objects" would be dispersed throughout the whole space. When average density of substances is equal to zero, it means that nothing can be seen, or there is nothing, not to say space-time image of objects. If we use characteristic volume of space-time r (radius of curvature) and R (curvature) (formed by whatever interaction) to characterize space-time image of "objects", then because $r=\infty$ and $R=0$, characteristic curvature surface corresponding to "objects" and characterizing "object" image (the characteristics of space time) is a plane surface. It is evident that, if "surface" in human concept could be connected with interaction of objects, "geometry" is organically connected with "physics" and the characteristics of space time of "objects". That is, in mathematics, plane surface and "objects" have no "space-time image"; the concepts that optical effects is zero and average density of substances is equal to zero are connected together. To expound more profoundly, without internal force, "noumenon" cannot stand on its own. This is the reason why philosophy of "noumenon" believes that there is no interactive "object".

External force is another kind of stress condition of substance. In physics, when "substance" has internal force, but no external force, or the sum of the action of external force is equal to zero, "objects" remain static or in uniform linear motion. And it is also stipulated that space-time coordinate constructed on object, static or in uniform linear motion is uniform straight space-time. Theoretically, if no external force is exerted on an object, and there are no observational signals, the object would not be recognized at all. As a result, it would be "nothing" in concept, and "nothing" is ze-

ro in origin. This is the spiritual essence of the human convention that space-time coordinate system constructed on "static" objects or objects in "uniform linear movement" is straight space-time. Plane and straight space-time is also the property that reflects an ideal world with no interaction. This feature is illustrated by space-time uniformity. Isaac Newton's absolute space-time is a uniform straight space-time, which is a silent world without interaction. It is identical with the logic requirement that, when there is no internal force, it is agreed that characteristic curvature surface connected with "objects" is planet surface. Vacuum can truly be "noting" (as in the case there is no internal force), or it can also be "nothing" in "something" (there is internal but no external force or the sum of the action of external force is equal to zero). In the latter case, only if relevant condition (certain external interaction) exists, "something" may appear from "nothing". Interaction breaks up the homogeneity of space-time, so "object" outstands, which is also the logic basis of the ancient Taoist philosophy, and the philosophic basis that, in quantum field theory, particles come into being and are annihilated in vacant space.

In brief, characteristic volume of object space-time $R=0(r=\infty)$ (plane surface) and equal value of "space-time straightness" in uniform motion coordinate system show no interaction, so substance or noumenon cannot be perceived. The premise that substances or noumenon are revealed and "visible structures" present themselves in space-time is that interaction has to be applied (including the role of observational signals) so that "substances" and noumenon express the space-time in the human comprehension. Thus, our first deduction is as follows:

Without interaction, "substantial noumenon" cannot form observed space-time image.

The reason that "substance" reveals its space-time image somewhere is that the action of force is exerted on it there (inclu-

ding the role of observational signals) so that object momentum and energy change and, accompanied with its process, basic physical volume of space time r and R connected with objects or space-time uniformity of coordinate system constructed on objects. When an object appears at place A, it may either the change of space structure of "object" at place A itself (from $R = 0$ to $R \neq 0$), or change of space-time uniformity of coordinate system constructed on objects that reveals the existence of the object. Both have connections either with internal or external forces. In microscopic world, dividing matter wave wavelength λ_n by 2π—the reciprocal of characteristic radius r_n, that is, "space-time structure" formed by curvature $R_n = p_n/\hbar$ expresses the measurable extent of "microscopic object". It is interaction, including the role of observational signal that enables us to understand the typical existence form of an object in space-time (or special space-time structure).

The action of force can change "space-time structure" connected with substance and reveal the existence of "objects"; while change of "space-time structure" where "objects" exist in turn affects motion condition of other objects, reveals certain moving tendency, embodies effective feature of certain force and shows certain field function where the object exists. Change of "space-time structure" constructed by field interaction and the objects is two sides of the same issue. The equivalence of accelerating field and uniform gravitational field is the premise of general theory of relativity, which reveals the inner relation of general theory of relativity and interaction principle. Thus, our second deduction is:

Where space-time change exists is also where "object" and field source exist.

According to the above interaction principle and its deduction, we will review and discuss the philosophic basis described by object's space-time image and state in Newtonian mechanics, relativistic mechanics and quantum mechanics.

On the basis of previous analysis, the cause of the formation of object's space-time image contains both the basic interaction that produces "noumenon" (natural force) and the role of observational signal. If theoretical abstract is not made on any object in the natural world, it is obviously not mass point, possesses characteristic volume r and R connected with interaction, and observational signal should also have effects on space-time image of substance. However, Newtonian mechanics simplified objects to mass points, which have no sizes and geometrical images. Substance itself has no image; what's more, because observational signal action speed in Newtonian mechanics is infinite, infinite signal speed cannot distinguish different space-time points in substance. Therefore, in Newtonian mechanics, observational signal cannot distinguish and effect the change of space-time image caused by object motion, which in fact neglects the effects of the role of observational signal on object's space-time image. Coordinate system is constructed on objects (reference), and the feature of space time of object (reference) is that of coordinate system. The neglecting of the influence of space-time image of observational signal on moving object (reference) means neglecting the influence of observational signal on space-time feature of coordinate system. Therefore, in Newtonian mechanics, space-time is absolute, having no relation with object motion. Looking from the effects of neglecting observational signal on the characteristics of space time of the "object", in Newtonian mechanics, "substance of appearance" is equal to mechanics of "noumenon"; the characteristics of space time of "substance of appearance" is also regarded as that of "noumenon". It is a simplistic and idealistic approximate hypothesis. In daily life, many of the human cognition and consideration on the natural phenomena are intentionally or unintentionally rooted in this principle of natural philosophy.

Thomas Kuhn's "irreductive pattern" mistook "substance of

appearance" for "noumenon". The philosophical origin of which may also comes from it.

Around the significance of mass point, Newtonian mechanics provided the hypothesis of logic uniformity, which is: ① Action speed of signal is infinite. Because all signals functioned on any points of object arrive simultaneously and different space-time point cannot be distinguished, so "object" is simplified as mass point. ② Intrinsic energy density of mass point is infinite and energy density is infinite, which indicates action of internal force of object is infinite. Therefore, infinite effects correspond to the implication of Newtonian mechanical mass point. ③ Newtonian mechanics is the extreme theory from the second of deduction. The characteristics of space time r and R of object adopt extreme value. The curvature of characteristic radius $r=0$, characteristic surface $R=\infty$, where all natural laws are invalid. In physics, odd point is used to express particle, and natural philosophic basis of odd point physic property should also originated from it.

Theory of relativistic mechanics is different. It denies the feature of infinite of light speed and acknowledges its limitedness, which in fact denies point particle feature of object. Albert Einstein's time checking experiment on train speed is a very good illustration that train is not mass point. To deny the point particle feature of object means acknowledge the effects of the function of observational signal on space-time image of object. The clock synchronization by light signals in the theory of relativity and limitedness of light speed on space-time feature just originated this new natural philosophic principle. Of course, in relativistic physics, object is finally changed to mass point, but that is realized by attributing the effects of the role of observational signal on space-time image of object (also as reference) to space-time feature of coordinate system. Object becomes mass point (coordinate system is constructed on mass point) and space-time image does not change, but space-time

of coordinate system connected with object (reference) is changing. This abstract treatment is reification of the extensive philosophic thoughts that "space is substance", which reflects the extraordinary wisdom of Albert Einstein. Relativistic mechanics, more accurate than Newtonian mechanics in the description of appearance, took into account both the basic interaction in Newtonian mechanics and the role of observational signal. However, it must be pointed out that when it considers the effects of observational signal (light) on space-time image of object, relativistic mechanics did not shake the position of basic interaction on space-time image of object, and the action of gravitation and light is regarded as continuous, thus forming space-time continuity. The effects of electromagnetic force on space-time can be transformed to that of gravitational change on space-time, which may be discussed later in the following chapter. Because the characteristic of space time is the product of interaction, continuous effects ensure the space-time continuity. These are the characteristics of macroscopic low speed and high speed worlds, which in microscopic world is another case.

In microscopic world, the action of photons and electrons is discontinuous, so electron abstracts or releases photons individually and discontinuously. Therefore, the characteristics of space time of electrons also become discontinuous. Disconnected interaction results in the existence of form catastrophe area. The volumes and directions of interaction between photons and electrons are also variable. Thus, characteristic volume r and R of electronic space-time formed by interaction is also changeable, reflecting the vibration of curvature R at different space-time points. However, each energy grade has a basic maximum value, appearing in amplitude of wave function, which is referred to as reference curvature (or base curvature). In our latest comprehension, this is essence of electronic wave. Electronic wave reflects the change of "self-space structure" ("surface curvature") expressed through optical phe-

nomenon in the process of electronic motion. We will also prove that, "space structure" —the changes of "image" and the appearance of point particle probability are interchangeable. Curvature interpretation may include probability interpretation, and make up the deficiency of "image" in probability interpretation.

3.2 Three Ways to Perceive Substance of Appearance and Logic Modes to Human Cognition of Nature

3.2.1 Three Ways to Perceive Substance of Appearance

In philosophy, the so-called "sensory presentation" did not involve scientific mechanism of the production of sensory presentation. Two hundred years ago, maybe people were unable to prove such mechanism. Nowadays, things are different, though. The rapid development of modern physics, modern bio-physiology, modern brain science, modern neuroscience and computer science has laid a good foundation for the research of scientific mechanism of "sensory presentation". In our studies, there are at least three different ways to understand "substance of appearance".

The first, "substance-in-itself", directly functioning on human senses (mainly visual system) through media such as light, arouses sensory presentation in human brain and constructs "substance of appearance" for human cognition. For example, through light, we can see that the moon or the sun is round. The image of the moon or the sun, directly functioning on our eyes through light, is synthetically constructed by the cerebral nervous system. Such is a kind of cognition. Modern brain science and modern neuroscience have done sufficient scientific studies on the action of the construction of this cognition. By examining the brain wave information of a person who is looking at an apple, we can see the image of the ap-

ple reappear on the computer screen. The moon, or the sun, or the apple one sees is not the "noumenon", but "substance of appearance" formed under the joint function of human eye-brain system through the medium (light). "Substance of appearance" is systematic and stable "sensory presentation".

The second, the transition of "substance-in-itself" to "substance of appearance" is not directly perceived by human sense organs and brain but formed into observed object in our brain through the extension of our sense organs—microscope or telescope. Microorganisms, cells, molecules, remote planets, etc. are cases in point. Of course, on one hand, visual presentation formed in this way, the same as in the first case, cannot be constructed independent of human eye-brain system; on the other hand, the principles and designs of instruments is inseparable from the human knowledge, theories and the logic system that have been constructed, and sensory presentation also has certain relation with human senses.

The last but not the least, there is an indirect way to perceive "substance of appearance". In such cases, the humans cannot directly perceive certain natural phenomena, but through personal observation construct "images" for the researched objects by the obtained experience, knowledge, theories and logic basis. Such "image" is not spiritual: it has the basis of the substances and the expressions of phenomena; it is physical reality and the research object of physics. In microscopic world, electrons cannot be seen with naked eyes, neither through high-power microscope. Our cognition of the images of microscopic objects like electrons is only on the basis of appearance observation, experience, knowledge, theories and relevant logic reasoning. It had been once imagined that an atom was like a raisin and electrons were inlayed like sand, and later it was found wrong. Afterwards, it was thought of as small balls of constant image rotating around atomic nucleus, and then found that it could not be established in atomic world. In atomic

world, electron is a unity of wave particle duality. What reality this wave particle duality is? Can the image of electrons change? Anyway, this damned electron still torments the human brains. As is the case, electron's reality might as well be dropped off, and it became nothing but a name of a pile of relations constructed by experience. Thus, only the relations were left, and the "knot" of the relation is missing. Then, what kind of substance is electron? Electron is nothing! This is the result of strengthening relations and neglecting the "knot"—starting point of the people who oppose scientific realism. Obviously, this idea is not acceptable, especially to the physicists who insist on the theory of reality. In fact, it is still the human goal to construct electronic "substance of appearance" that fits the objective reality.

The "substance of appearance" that the humans have constructed through their own sense organs or the extension of these organs is objective existence, and the "substance of appearance" that the humans have constructed through appearance observation, experience, knowledge and logic reasoning is also objective existence. The moon, the sun, and the remote planets are realistic existence, so are microorganisms, cells and molecules. In quantum mechanics, microscopic objects are reality, such as the electrons with wave particle duality. Only, "substance of appearance" is constructed in the third way mentioned above.

Actually, in history, the third way is applied in the human cognition of the image of the earth. In ancient Greece, it was once believed reasonable to think of the earth as of spherical image. But standing on the earth, people only feel a flat earth. A spherical earth is confirmed by sailing around the earth and then returning to the starting point or by seeing the mast first and then the boat on the sea level. It reveals that construction by reasoning is the first and to be confirmed later. Of course, we can see spherical earth directly from spaceship nowadays, but that is the result of the ad-

vance of science and technology. It proves that "substance of appearance" known through experience, knowledge, theories and logic reasoning also possesses its reality, so will the human cognition of electrons. What must be pointed out is that, we are not constructing "substance-in-itself" (noumenon) but the image of the "substance-in-itself". "Substance-in-itself", only with the recognized "image", can be transformed to "substance of appearance". Therefore, what we construct is "substance of appearance", and "noumenon" cannot be constructed. Nevertheless, "substance of appearance" is not equal to "appearance". "Substance of appearance" is a concept in physics and philosophy.

It is believed that, in Newtonian mechanics, the image of substance of appearance in discussion has no effects on discussed issues and can be ignored. The objects described in physics—physical substances—are abstracted to mass point. Physical substance is realistic existence and mass point in Newtonian mechanics represents physical substance. In relativistic mechanics, mass point also represents physical reality, and in general theory of relativity, widely distributed field is also physical reality. Time and space, affected by substance distribution, also becomes a kind of physical reality in geometrical field. What is the expression of physical reality of microscopic objects in quantum mechanics, such as electrons? And is the mass point with its "image" neglected? The problem is that we are still very confused about what the "image" of electrons is. If the "image" is ignored without knowing what it is, can we avoid problems in our cognition of electrons?

It should be the common sense that human cognition of the real macroscopic world is based on macroscopic continuous effect. The "substance of appearance" human brain identifies through continuous effect of light is a continuous image. In fact, the human adaptation of non-continuous irradiation is very weak. Movie, if twenty-four pictures less in a second, cannot form continuous im-

age. In atomic world, electrons in energy level transition only emits non-continuous spectrum, with which it is very difficult for the human brains to construct the image of electrons in atoms, for it is beyond the ability of human brain. Moreover, besides principal quantum number, there is non-continuous concept ($h \neq 0$) like angular quantum number, magnetic quantum number and spin quantum number in the electrons of atoms. To say that electron is a smooth ball of the same size and that it can be abstracted to mass point is purely a classical imagination on the ground of macroscopic continuous effect ($h=0$). Ernest Rutherford's atom model met a setback in this imagination.

The function of microscopic world is non-continuous, and human brain is unable to construct the image of non-irradiated objects directly so that it cannot accomplish the transition from "noumenon" to "substance of appearance". However, the humans must accomplish such transition, or their complete cognition of the electrons in atoms will be impossible. In the above mentioned three ways, only the last one can be applied in the transition from "substance-in-itself" to "substance of appearance". To understand microscopic objects, we must construct their images with our experience, knowledge, theories and relevant logical basis through the optical appearance they give out. The constructed "substance of appearance" of electron is bound to possess wave particle duality. It is not spiritual but the down-to-earth physical reality, for this physical reality can be demonstrated through its optical appearance. To be more specific, through quantum measurement (the role of continuous effect), "substance of appearance" corresponding to microscopic objects such as electrons in atoms and constructed in the third way, may present macroscopic classical particle property. It is reported that, the humans are making experimental measurement on electron transition in atoms.

Physicists should notice that, even if electron in energy level

transition is successfully measured in the future, it is only the electron emerging after continuous effect is involved, which is not equivalent to the electron in non-continuous effect before the measurement. Measurement changes the image of "electron".

3. 2. 2 Construction of Image of Electron in Atom and Physical Sense of Matter Wave

In atoms, electron radiates photon at energy level transition, and photon energy $E_{light} = h\nu = E_2 - E_1$, E_2 and E_1 are energy of electron at energy levels 2 and 1; ν is frequency of light. Photon energy directly shows the change of electronic energy and momentum. Electronic momentum and Louis de Broglie matter wave wavelength of electron have direct relations while wave length and space concept are interrelated. In physics, Compton wavelength is often used to divide $2\pi(\bar{\lambda}_0 = \lambda_0/2\pi = r_0)$ as characteristic length of static particle. Our research illustrates that, there is experimental basis to regard this characteristic length as the distribution radius of static particle. Experiments were made by Hoffstadt, American experimental physicist, to examine the distribution radius of neutrons and protons [7] and the measurement of electron distribution radius by the others, the data of which well accord with characteristic length. [8] It is evident that there is experimental basis on constructing electronic "image" with wave length. (See appendix 2)

Static electron is not atomic electron (electron in the atom), and the characteristic length of static particle is not appropriate for it. Atomic electron keeps moving, from one energy level transition to another. So, what we see is frequency and intensity of light, not continuous spectrum lines. Discontinuous light spectrum will not establish a continuous image of electron in the brain. However, Louis de Broglie matter wave wavelength of atomic electron has the space concept. Similarly, we try to divide Louis de Broglie matter wave wavelength λ_n by 2π $(\lambda_n/2\pi = \bar{\lambda}_n)$ as standard curvature radius

r_n of electron at atomic energy level n. In hydrogen atom, this radius r_n can be described as: $r_n = na_0$, in which n is principal quantum number, a_0 is Bohr radius, and $R_n = 1/r_n$ is phase circle curvature; from amplitude of hydrogen atom and wave function of other matter wave, curvature factor $1/r_n$ can be separated. At each energy level a standard curvature R_n corresponds to electron, and at each space-time point curvature corresponding to the electron pair is changing. Thus, we believe that matter wave is curvature wave. The bending degree of curvature reveals corpuscular property of electron and curvature change shows undulatory property of electron. [9] Undulatory property and corpuscular property are unified and harmonious in atomic world.

The closer to atomic nucleus the atomic electron is, the bigger the curvature scale R_n, the higher the photon frequency irradiated at energy level transition; the farther away from atomic nucleus the atomic electron is, the smaller the bending degree of curvature R_n, the lower the photon frequency irradiated at energy level transition. The closer to atomic nucleus the atomic electron is, the bigger the bending degree of curvature, the smaller the "image", the better the chance is to find point electron in the "image", the higher the electron transition probability, the stronger the light is; the farther away from atomic nucleus the atomic electron is, the smaller the bending degree of curvature, the bigger the "image", the less the chance is to find point electron in the "image", the lower the electron transition probability, the weaker the light is. Curvature interpretation fully makes use of the function light plays in human establishment of objective "image", which is named "light-image transition"; curvature interpretation also uses the relations between "image" and mass point to establish correspondence and connections between probability interpretation and curvature interpretation, which we call "image-point transition". Curvature interpretation also includes probability interpretation. We can also prove

that, in atom, the idea that the "image" we constructed for electron is not to be ignored in the depth of atom has lost the condition to abstract macroscopic mass point. [10] If atomic electron is bound to be abstracted to mass point, the distribution error of the position of point electron will occur, and the scope of error is distribution radius of the "image" of electron. "Point" electron has its new property, and that is the uncertainty of "mass point" in its "image". While mass point is virtual wave is real, exhibiting the change of characteristic volume of space determined by momentum. In atomic world, curvature wave and virtual particle together structure physical reality of electron—the description object of quantum mechanics.

Niels Bohr had explained the unity of wave particles with complementary principle. Later, it was further explained in a vivid and philosophic image illustration. Looking at the dark part of the image, there are two persons face to face; while looking at the blank part of the two faces, there is a vase. It is an image of two faces or a vase? Both and neither! The "vibrating" curve at the border of black and white happens to express the faces and the vase. This "wave" is the wave of faces and vase; thus, two unrelated things are interrelated.

However, in the interpretation of quantum mechanic curvature, the border line of black and white of this design was replaced by circumference of phase circle surrounded by matter wave wavelength. Looking at the dark part, the circle curvature expresses bending degree of the curved line, representing the "image" of microscopic object; looking at the white part in the circle, the borderline of black and white expresses the probability to find virtual particle in the circle. When "image" is small, the bending degree of curvature is big, the probability to find it is big; when "image" is big, the bending degree of curvature is small, and the probability is small. Corpuscular property and undulatory property have reached

ideal unified expression along the borderline of black and white.

Nevertheless, what should be further explained is that, the human cognition of the "image" of "substance of appearance" also depends on "substance of appearance" and the existing condition of "substance of appearance", to see whether it could be separated from background space. In the world of macroscopic continuous effect, the separation of object and background space better increases image-distinguishing and constructing abilities of human eye-brain system. In the microscopic world, if "image" cannot be neglected in the discussion of atom issues, it indicates that it is difficult to separate object and environment. Then, when object motion is discussed, it is hard to describe it with mass point of the image abstracted from space; so we have to change to describe it with the characteristics of space-time the object shows at different space-time points. This is the physic significance of wave function in quantum mechanics, whose objective reality is beyond all doubt.

3.2.3 Logic Modes in Human Cognition of the Nature

In their cognition of the natural world, the human beings cannot do without three basic key elements—subjects, objects (noumenon) and observational signals, the relations between which and "appearance" (object's space-time characteristics) construct the logic foundation in human cognition of the nature.

However, before discussing the logic foundation in human cognition of the nature, we have to make further analysis of certain important concepts.

①Noumenon (object): objective reality that is related with basic interaction but not with subject. If it were to be observed without certain observational signals, the human beings would not know what "noumenon" is.

②Subject: Man is the subject in cognition of nature and the society. Without subjects, the "value system" related to the human

beings would become meaningless.

③"Appearance": Generally refers to phenomenon, and space-time characteristics of substance of appearance.

④Observational signal: all objects existing in the world interact with each other. Presently, four basic interactions are found: gravitational force, electromagnetic force, strong interaction force and weak interaction force, which are the four signals the human beings use to observe noumenon, especially electromagnetic signal which is the most basic and commonly used. If it were not for the observational signals, it would be impossible for the human beings to transform noumenon into the known natural appearance.

⑤Meaning: refers to the value system in which the humans evaluate natural appearance. Without subject, the value of any natural appearance is reduced to zero, that is, the meaning is none.

After the above five basic concepts are clearly understood, the logic equation is established in the human cognition of the nature, as follows:

Subject + observational signal + noumenon (object) = "Appearance" • meaning

Or:
$$A+B+C=D \cdot E \tag{3.1}$$

Here, $A=$ subject, $B=$ observational signal, $C=$ noumenon (observing object), $D=$"Appearance", $E=$meaning, $\cdot$ = multiple sign (refer to Note in the first part of this chapter). The left of the equation is the three fundamental factors of the human cognition of the nature, and the right is the cognition result.

① Given B(observational signal) $=0$, then D("Appearance") $=0$

That is:
$$A(\text{subject}) + C(\text{noumenon}) = 0 \tag{3.2}$$

The above equation shows: without observational signal, subject (man) would have no way to understand natural phenomena and noumenon could not be turned to what man has known as appearance, substance of appearance, that is, cognitive target: "Appearance" $=0$, which is easy to comprehend. Just think if the hu-

man beings exist in a "dark" world without information, what can we know in the world? When noumenon could not be turned to the known "substance of appearance", although noumenon exists, there would be no "Appearance", which explains why "Appearance" would be none.

② A(subject)=0, then D("Appearance")=0, E(Meaning)=0,

That is, B(observational signal)+C(noumenon)=0 (3. 3)

Equation(3. 3)shows that, if the subject of cognition (man) is lost in the world, then, noumenon in the world could not be transformed to what the humans have known as "Appearance", and all the value system defined by the humans would either lose their meanings, which is $D=0, E=0$, similar to the cognition by the philosopher, W. Nietzsche. The existence away from the human observation is only abstract existence, which merely has its philosophic meaning but no practical meaning.

③ C(noumenon)=0, then D("Appearance")=0

That is, A(subject)+B(observational signal)=0 (3. 4)

Equation(3. 4) indicates that, only when observational signal acts on noumenon, can a practical existence valuable to the humans be obtained—appearance, substance of appearance. without noumenon, observational signal would have no target to act on, then "Appearance"=0. In fact, if the noumenon in equation(3. 4)does not exist, subject and observational signal would not exist either. Because subject (man) and observational signal in nature are also constructed by noumenon, without noumenon, there would be no world: where are man and observational signal?

Idealists believe that consciousness determines substance, that consciousness is the first and substance the second. Equation(3. 4) will help us to analyze the logic origination of idealist epistemology and point out where its deviation starts from.

Consciousness is characteristic of subject, and subject attributes to noumenon in view of the property of substance. If there

were no noumenon, that is, if there is no man, where does consciousness come from? Idealist fallacy is that it does not understand (or it is unwilling to understand) subject (man) himself is also constructed by substantial noumenon. The disappearance of noumenon would lead to the disappearance of thinking process, and then the human consciousness would vanish naturally, where is the consciousness that determines objects?

When we know that thinking (or consciousness) itself also has material properties, the world is unified with substances. The relation between thinking (consciousness) and substance is not which determines which but how this substance was originated that corresponds to thinking (and consciousness). What we will further study is the physical and chemical processes of the production of this substance corresponding to consciousness in the human brain. This is the subject of scientific research in present world brain science and thinking.

It is evident that, the three key factors are indispensable in the human cognition of the nature. To know the world comprehensively and correctly, it has to be $A \neq 0$, $B \neq 0$, $C \neq 0$, and finally guarantees $D \cdot E \neq 0$, which is the necessary prerequisite of correct cognition of the world—logic equation (3-1).

Newtonian mechanics is that of "noumenon" = substance of appearance, which on one hand ignored the effect of the subject (man) in knowing the natural appearance, on the other hand the effects of man on observed object when he used observational signal. The logic equation of Newtonian mechanic epistemology is:

Noumenon = substance of appearance

That is, the space-time characteristics of substance of appearance are that of noumenon, which is obviously uncompleted.

Relativistic mechanics took into consideration the effects of the role of the observational signal on "substance-it-itself" in the visualization of space-time, but was not certain about the position of

subject (man). If the subject were not man but other creature, its theoretic structure would change correspondingly, that is, resulting in the change of observational signal or maximum speed c. Light is human observational signal (timing signal), while other creatures may use other communicational signal. For example, bat uses sonic wave, so its theoretic structure and the description of appearance and "substance of appearance" may be completely different from that of the human beings. History indicates that, the human beings can transform the cognition of other beings into human cognition, which is the precious human ability.

The description of the microscopic world by quantum mechanics, especially the orthodox quantum mechanics of Copenhagen School, had not only considered the effect of observational signal (light), but in the theory of quantum measurement also considered mechanism of quantum probability to macroscopic classical probability. Thus, the process of the establishment of quantum mechanics should have agreed with the logic pattern of human cognition of the nature. However, unfortunately, on one hand, it blindly regarded the described object of wave function as "quantum probability", but not the wave image property of electron in space-time; on the other hand, it directly attributed the effects of observational signal on space-time image of object to that of thinking on object. It is the task of the "quantum mechanic curvature interpretation" to correct this cognitive deviation.

It should be noticed that, when we emphasize the main position of man in understanding the objective world, we are not stressing what interference effect the human subjective consciousness has on noumenon, but saying that when man perceives the objective world—"noumenon", observational signal is bound to influence noumenon, while consciousness (human brain's activity) has nothing to do with the laws of motion of object (noumenon), and what it does is to actively reflect the objective world, and its physical,

chemical and physiological reaction corresponds with the function of observational signal. For this, Werner Karl Heisenberg has made an incisive interpretation: "Quantum theory does not contain real subjective characteristics, nor does it introduce physicist spirit as part of atomic issues." In dialectic viewpoint, as an observer, man himself is inseparable part of the nature (the observed); man only observes the nature in the nature, and naturally applies natural signal as his observational signal. Thus, in internalization viewpoint, not only the interaction between substance-in-itself is unavoidable but that if observer and substance-in-itself is also indispensable. To sum up, it is emphasized that the human cognition of the nature is overall product of interaction between noumenon and observational signal, and it not only fully agrees with materialism but completely suits dialectics.

3.3 Existence, Reality and the Openness of Substance of Appearance

General interaction principle points out that each object reflects the generality of connection through itself and demonstrates their own existence through the generality of connection. "Substance is of its own cause", "Interaction is the final reason of things", which indicate that objects indicate the reality of their own in interrelation and interaction.

Special interactive principle attempts to make the human cognition of the nature more scientific and more concrete; it tries to put together the good aspects of philosophic thinking of the philosophers, as Friedrich Engels, Immanuel Kant, Ernst Mach, and Rene Descartes, and blend them together with modern science so as to reveal the scientific advance in human cognition of the nature. We clearly see that, Newtonian mechanics, relativistic mechanics, and quantum mechanics all describe objective world and reveal the

"reality" and the scientific theories of its laws of movement at certain cognitive level through interaction (including the role of observational signal).

"Substance is the objective existence we have felt". Here, "objective existence" mentioned by V. I. Lenin is what we have meant by "substance of appearance" or "physical reality". How can man "feel"? Of course, we feel in different ways: first, by depending on our own senses; second, with the extension of our senses—instruments; and the third, by inference through appearance. However, whether directly through sensory feelings, or indirectly through instrumental feelings, or through appearance reasoning, to "feel" that observed target is objective existence, we should depend on the communication of interaction information. It is with the help of light that we can see mountains and rivers, lakes, stars, the moon, buildings, and villages. Walking on the ground, we feel that the ground is "objective existence", due to the attraction of gravitation and the friction of foot on the ground. Walking towards a wall, man would walk through it if the wall has no direct resistance to man and there would be no way to sense the "objective reality" of the wall. Ernest Rutherford used α-particle to bombard atom. If there were no interaction between atomic nucleus and α-particle to scatter α-particle, it can be imagined that the human beings would not know what atomic structure would be like. When a group of α-particles are hit into the target, they enter it as if they enter vacant space; then, how the human beings "feel" the "objective reality" of the target? Maybe one would say that, target could be "felt" with hands. Notice: once it is "felt" interaction is introduced. Therefore, we may say that the stronger the interaction between objects, the easier the "objective reality" of substance is perceived; the weaker the interaction is, the more difficult the "objective reality" of substance is perceived; without interaction, the "objective reality" of objects is not to be perceived. The "objective

reality" of substance is perceived through interaction, or presented through interaction.

The physical reality of "substance of appearance" is presented through the human observational function.

The above discussion is above the human "perception". Objective reality should be independent of man's subjective cognition. Then, how "objective reality" is perceived among substances? Motion is the basic property of substance, the interaction among which is the friendly "angel" for substances to "perceive" "reality". "Substance invariably acts on other substance as power source and thus reassures its existence."[11] The "force" Albert Einstein referred here is in fact a kind of field. Electromagnetic effect has reality perceived among electric charges: "attraction" and "expelling" are forms of expression of "perceiving reality". Gravitational field enables objects to perceive the reality among them, and attraction is a form of expression for them to perceive each other. Weak interaction force, in nature, is of the same origin of electromagnetic force, which is another form of expression of weak electric power. And strong interaction is the force that nucleons "perceive" each other. A particle not joining strong interaction will be unknown when probing with strong field just as when probing neutron with electromagnetic field we do not know what the neutron is, if the neutron is not the neutralization of two substances of electrical property. "Field" only knows its "full brothers" but is completely ignorant of "other sisters". We cannot use field substance having no interaction between them to "perceive" the "reality" of the other substances. No reality can be perceived between substances that have no interaction, whether between the human beings and the nature, or in the nature itself. In a world that is completely motionless, the field substances that convey interaction among them would diminish, and substances could not "perceive" each other's reality. A world without reality is completely of "nothing". It

means that, a world without interaction does not "exist". It proves from the other side the philosophic principle that, motion is the basic attribute of substances, the world is made up of substances in motion and that object completely motionless does not exist.

Away from the human observation, the "reality" presented by interaction of substances in our imagination is what is defined as "real being", which corresponds with "noumenon". The "reality" of noumenon is recognized through the reality of substance of appearance.

The motion of substances is space-time motion, the existence of substances is space-time existence, and boson field is the "angel" of substances perceiving reality of each other. Owning to the difference of the motion condition and the difference of the field property, the existing patterns (reality) of the substances the human beings perceive is different. In dark night, when objects are irradiated with red light, they reflect red light and present red color; when objects are irradiated with purple light, they reflect purple light and appear in purple color. To be irradiated with weakly interaction field, substances will have not any "perception" at all. Field substances are unable to perceive the "objective reality" of objects if they could penetrate the objects. Whether substance is red, or purple, or not "existent", the result is different if the field information applied to perceive the "existence" of the other objects is different. Therefore, the substances we know are bound to possess "perception field bias" in space-time image, only that some are known, and some are unknown. Maybe we cannot explain clearly what on earth substances will have, but we can explain clearly what substances are now! The objective reality of all substances is perceived through interactions. Interactions are various and reality is open. With the transition of survey information, we can know more about the unknown properties of objects (which is different with agnosticism). We can also discover things thought "non-exist-

ent" in the past, and things thought existent may disappear without any trace at certain circumstances. This fully reveals the glamour of interaction of "perception reality". Through weak interaction, the human beings realize the existence of neutrinos, which provides a very good example. It is related with the applied detective field information whether an object "exists", or how it "exists", or whether the object can be perceived, or what the perception image is. If curvature is used to indicate the image of the object, "curvature" will change as field function varies. Presently, the "perception field" the human beings have used is gravitational field (perception mass "m"), electromagnetic field (perception electric charge "q"), strong interaction field (perception of "strong charge"), weak interaction field (perception of "weak charge"), etc. We do not have to worry that, if something does not exist in certain detection field (something which has lost certain "reality"), its substance would disappear in the world. Dialectical materialist "being—substance" is the whole of "physical reality"(substance of appearance)identified by interrelations and interactions.

In addition, interactive principle also tells us that, what interactions there are, there are what theoretic structures. Changes in the quality of interactions will cause the changes in the quality of theoretic structure. The change of theoretic structures of the relativistic mechanics and Newtonian mechanics in observational processes is the change of light speed from infinite to finite; the change of theoretic structures of classical mechanics and the theoretic structure of quantum mechanics lies in the coming-into-being of energy quantum, non-neglect of "image" and the change of interaction from continuity to non-continuity. In different cognition levels, interaction changes, and the theoretic structure will change, and substance of appearance also changes. Thus, noumenon presents a new look. Substance of appearance is constructive and noumenon is not. The structure of scientific theories is open.

This is our theory of interactive constructive reality. "Construction", as a scientific process of cognition, is open.

Now, the flow chart of the process of the human cognition of nature will give a more detailed illustration as follows: see chart (3-2).

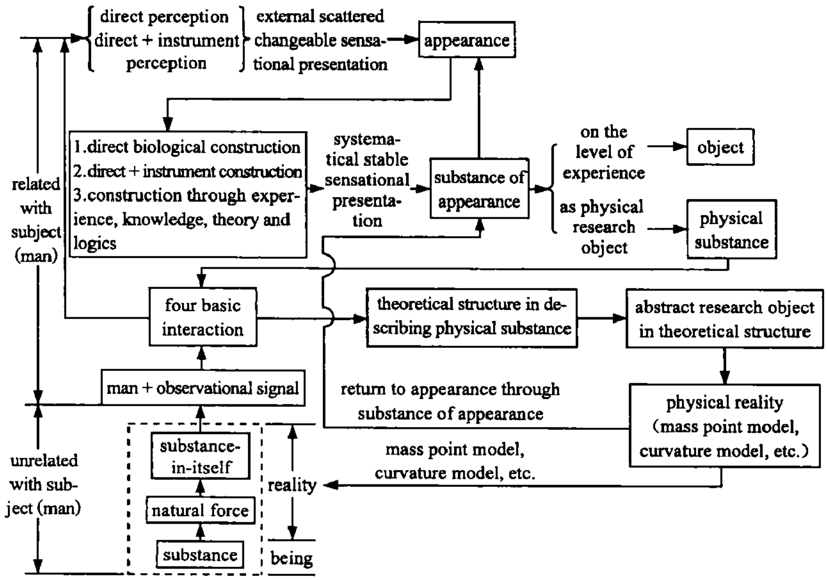


Diagram 3. 2 the logical equation of the human cognition of the nature

Interpretation of the chart: At first, the human cognition of noumenon was "appearance", which was external, scattered, and changeable "perception appearance". Through human biological construction (scientific cognitive process), systematic and stable "perceived appearance" was formed, which is "substance of appearance". "Substance of appearance" remains at experiential level as "objects" in daily life; it is "physical substance" as "objects" of physical research. The laws of motion of "physical substance" in given interaction are revealed by theoretic structure. And in theoretic structure, abstract research target is "physical reality". For

example, mass-point model, curvature model and others are all physical reality. Through "physical reality", we can know noumenon, which is unchangeable. The changeable interaction will cause the variation and openness of substance of appearance. Substance of appearance is constructive, of course, so is physical substance, and so is physical reality. It is the different presentation of noumenon, and through physical reality, noumenon can either be perceived or reduced to appearance. In the chart, the process "substance of appearance"→physical substance→interaction→theoretic structure of physical substance→ research object in theoretic structure→physical reality (mass-point model, curvature model) reveals the third cognitive process in constructing "sensory appearance" - "substance of appearance"—from experience, knowledge, theories, and logics.

The above chart wonderfully shows the logical track of cognition, the both ends of which is connected.

Reference

[1] Jin, Wulun. Generated Philosophy [M]. Shijiazhuang: Hebei University Press, 2000:4,215.

[2] Ma Quanmin et al. Interpretation of Philosophical terms (Book 1) [M]. Beijing: People's Publishing House, 1982: 110.

[3] Feng Qi. Philosophy Dictionary [M]. Dictionary Publishing House of Shanghai, 2001:1579 and 1582.

[4] Immanuel Kant. Prolegomena to Any Future Metaphysics [M]. Dictionary Publishing House of Shanghai, 2001:710.

[5] Hong Dingguo. Theory of Physical Reality [M]. Beijing: Commercial Press, 2001:110-118.

[6] Luo Jiachang. From Substantial Noumenon to Relation Reality [M]. Beijimg:China Social Sciences Publishing House, 1996:

349-358.

[7] Richard Philips Feynman, C. Miller. Contemporary Physics [M]. Translated by Ye Yue and others, Beijing: Science Press, 1981:168-173.

[8] Ni Guangjiong et al. Modern Physics [M]. Shanghai Science & Technology Press, 1979:146.

[9][10] Zhao Guoqiu and Gui Qiquan. New Divine Comedy of Physics [M]. Wuhan Publishing House, 2004:241-294.

[11] Albert Einstein. Evolution of Physics [M]. Translated by Zhou Zhaowei. Shanghai Science & Technology Press, 1964: 35.

第三章 相互作用原理

第一节 广义与狭义相互作用原理

相互作用原理包括广义相互作用原理和狭义相互作用原理两部分。

一、广义相互作用原理

广义相互作用原理是指事物间的普遍联系。联系作为一个哲学范畴，指一切事物、现象之间及事物、现象内部诸要素之间的相互作用、相互影响、相互制约的关系。一事物、现象及其过程与他事物、现象及其过程之间的相互作用、相互影响、相互制约的关系称为外部联系；事物、现象及其过程内部诸要素之间的相互作用、相互影响、相互制约的关系称为内部联系。

事物之间的普遍联系具有客观性、普遍性和多样性。联系的客观性表明，联系不是人们的主观臆造，而是不以人的意志为转移的客观事物，是事物固有的本性。人们可以发现联系，但不能创造联系。联系的普遍性指出，世界上一切事物、现象及其过程的内部和外部都处在相互联系中，世界上没有"没有相互联系的事物"，整个世界是一个相互联系的统一体。孤立的、静止的、彼此没有任何联系的事物是没有的。"实体是它自身的原因"(斯宾诺莎)，每一事物通过其自身体现出联系的普遍性，又通过联系的普遍性表明它自身的存在和真实性。自然界如此，人类社会亦如此。联系的多样性与世界极其广大和发展的无限性相关。事物联系的主要形式有：因果联系、必然联

系和偶然联系、本质联系和非本质联系。因果联系是包括时间先后次序在内的，由一种现象必然引起另一种现象的内在本质联系。必然联系是事物存在和发展的内在规定性，规定事物发展的基本趋向，它由事物内部的基本矛盾所决定。偶然联系表明事物出现的或然性。事物既可以出现，也可以不出现；既可以这样出现，也可以那样出现。这就是偶然性。唯物主义认为，事物的偶然联系是事物存在和发展的外在规定性，由事物的外部条件或事物内部的非基本矛盾所决定。本质联系是反映事物本来面目的基本联系，它决定事物的根本性质。非本质联系是事物的表面特征和外部联系，是事物的假像表现。真像是事物本质直接的表现，假像是事物本质歪曲的表现，往往事物的真像易被假像所掩盖。真像和假像都是客观的。以为假像与本质毫无关联的看法是有违于辩证法的。即假像仍是本质自身特殊形式的表现。事物的现象是必定与事物的本质相联系，而事物的本质就是事物发展的规律。规律是本质联系，现象是非本质联系。

事物普遍联系的具体形式还有：直接联系和间接联系、内部联系和外部联系、主要联系和次要联系等等。

透过现象看本质是唯物主义者研究自然和人类社会的基本要义。

世界上的万事万物都是普遍联系的，而普遍联系包含着相互作用，“相互作用是事物的真正的终极原因”，[1]可见无论是自然界，还是人类社会，任何事物都是在其相互联系、相互作用中表现其存在的，世界上没有孤立的、静止的、无相互联系、无相互作用的事物。

二、狭义相互作用原理

与传统的表象理论不同，狭义相互作用原理指明人类认知的自然现象是如何形成的，强调复杂的科学认知过程。它说明人与自然的关系。

（一）几个相关概念及其相互联系

①物质。

物质——外在世界的本原，万物的基始。哲学上的物质，它是抽象的，无所谓形体概念。物理学中的原子、电子、基本粒子，以至夸克、超弦等都不能等同视作哲学上的本原。它只能是物质本原在物理学中的具体体现。

②自在实体(本体)。

指人类意识之外独立存在的客体。“月亮在不看它时作为月球照样存在”,“自在实体”不是不可知之物,“月球”就是我们所称的“自在实体”(本体),但“月球”通过观察转化成为“月亮”,转化成“为我之物”[2]。世界上没有不可知的东西,昔日不可知,今日变成可知。这种转化就是认识。

物质与“存在”相对应,“自在实体”与“实在”相对应。

“自在实体”与“物质”相比,在“形”的构成上前进了一步。它已经出现了“体”的概念。这个“体”如何形成,哲学家们没有过多地追究。有物质就有相互作用,物质与相互作用相辅相成,没有谁先谁后的问题。从“相互作用”这个普遍的形上概念看,相互作用应是“体”形成的原因。相互作用使物质形成了本体,并可呈现为某种关系的“纽结”。尽管相互作用可体现为某种物质(玻色子)的交换,但由于相互作用在这里仍是一个普遍抽象概念,因而本体是什么样子,人类不去观察就不知道,但不是不可认识。因为有了“体”,按洛克的说法是“物质实体”[3],因此,本体是本体论中的“实在”,比“存在”向现实世界走近了一步。然而,本体如果不与人类使用的观测信号,例如光发生作用,其形象和实在性将不被人类所感知。因此,结合洛克的概念,我们把本体称作“自在实体”。与物质概念相比,“本体”已经通过“自然力”的相互作用“凝聚”成“体”了,“只是这些物体本身可能是什么样子,我们一点也不知道。”[4]

本书将“存在”与“实在”做了区分。“存在”不同于“实在”,谈到“实在”就强调了相互作用,“存在”与“物质”概念对应,“实在”与“自在实体”、“物理实体”等概念对应。

③物理实体。

现行哲学辞典中没有这一概念,但广为物理学家和物理学哲学家所使用。指物理理论所指称的研究对象。[5]按照经典物理学,从物质形态上划分,物理实体有气态、液态、固态三大类形态。气态无形无体(无一定的体积),液态无形有体(有一定的体积),固态有形有体。从结构上划分,物理实体则有分子、原子、原子核、电子、质子、中子等等。有的知道“形”,有的不知道“形”,例如原子中的电子,我们就不知道它的形状。分析还原论者认为,原子、电子等微观客体在系

统内和系统外具有不变的特性，例如原子中的电子与从原子中分离出来的电子就具有相同的属性。

物理实体与本体相比，它体现了四种具体自然力（引力、电磁力、弱力、强力）对形成“体”的作用。它能帮助人类对本体的具体认知。不同的自然力，物理理论所指称的研究对象——物理实体的表现也不一样。它们分别以质量载体（m）、电荷载体（q）、弱荷载体（g）、强荷载体（G）加以区别。

物理实体在牛顿力学、相对论力学及现行量子力学中“形”都忽略不计，抽象成了质点。质点是一个没有“大小”，但有“实”的东西。物理理论所指称的研究对象——物理实体均是物理实在。

④现象实体。

与自在实体相对。现行哲学辞典中没有这一概念。按现行哲学概念，“现象”指“自在之物”——本体作用于人的感官所引起的感觉表象，是事物外在的、零散的、易变的方面；“实体”通常指能够独立存在，作为一切属性的基础和万物本原的东西。实体与现象相对，是现象所依存的本体。现象与实体放在一起组成新的概念，看来有些矛盾。是现象就不是实体，是实体就不是现象。那么既是现象又是实体的“现象实体”指的是什么呢？现象是“自在实体”（自在之物）作用于人的感官所引起的感觉表象，这个感觉表象是外在的、零散的、易变的，有时具有形体概念，有时却没有。这既与“自在实体”本身有关，还与中介信息和人的视觉识别能力有关。我们把现象与实体共同组成“现象实体”，主要是强调感觉表象中“客体”稳定“形体”的一面，强调既有“象”又有“形”，还有“体”的客观认知过程。“现象实体”是“本体”通过观测信号作用，由人的感官或感官的延伸与大脑神经系统综合作用引起的系统的、稳定的感觉表象。它表明人对客观世界的认知有一个科学的物质作用过程。感觉表象是人脑的一种生物建构。“现象实体”是本体在特定条件下的一个具体体现，尽管与人脑接收的中介传媒的性质和人脑的结构有关，但它是客观实在的。当现象实体作为物理学研究对象时，就构成物理实体。现象实体概念的引入，将对我们理解量子力学指称的研究对象有重要帮助。

“现象实体”的提出是科学认知过程的补充，是对“表象”理论的改进，这是康德时代无法办到的。

"范式不可通约"是库恩误把"现象实体"当"本体"所做的错误结论。

⑤观测信号。

人类认知世界借以使用的探测信号。没有观测信号，人类就不知道"本体"是什么。也无法认识四种基本"自然力"的作用规律。观测信号的性质，直接影响人类对"本体"的观测结果，其中包括"现象实体"的时空特征。因此，凡涉及"现象实体"，人的主体作用就加进来了。"物体"、"现象"这些概念，都有人的主体作用成分。人类认知世界的"中介观测信号"是感觉表象必备的客观基础。

观测信号作用与人的经验对应。人类认识的时空必然要打上"现象实体"时空特征的烙印。空间即物质广延性的哲学思想有了物理学基础。

⑥"现象实体还原为本体"：特指不计观测信号作用在人类认识世界过程中的影响，包括不计对"本体"时空特征的影响。这样，"现象实体"的时空特征就可以理解为"本体"的时空特征。我们将要说明牛顿力学就近似于这样的力学。

⑦"本体"转化为"现象实体"：是指承认观测信号作用对人类认识世界的影响，也即承认观测信号作用对"本体"时空特征的影响。

⑧基本相互作用：泛指普遍的自然力。经观察，现今人类认识了引力、电磁力、强力、弱力等四种基本相互作用。

⑨价值和意义：我们认为，如果没有人，自然界中的一切均无所谓价值和意义。"现象实体"的价值和意义是相对于人而言的。这与尼采的观点类似。

⑩乘号"·"：在语义解释上表示"现象"与"意义"的依存关系，在句法的直观意义上是算术的，如果证明是"群论"的（即在句法上纳入广义运算的规则体系），则可能有新的预见[见逻辑通式(3.1)]。上述概念的逻辑层次见图3.1，"现象"泛指现象、现象实体的时空特征。

在日常生活中，通常人们把本体通过观测信号到现象实体的认识过程忽视掉了，直接从"自然力"的相互作用到现象实体，这样，物质常被看成是本体。

科学实在论的真理派，把现象实体误认为自在实体，抹杀了自在实体与现象实体的区别；反科学实在论的经验主义者则是只看到了

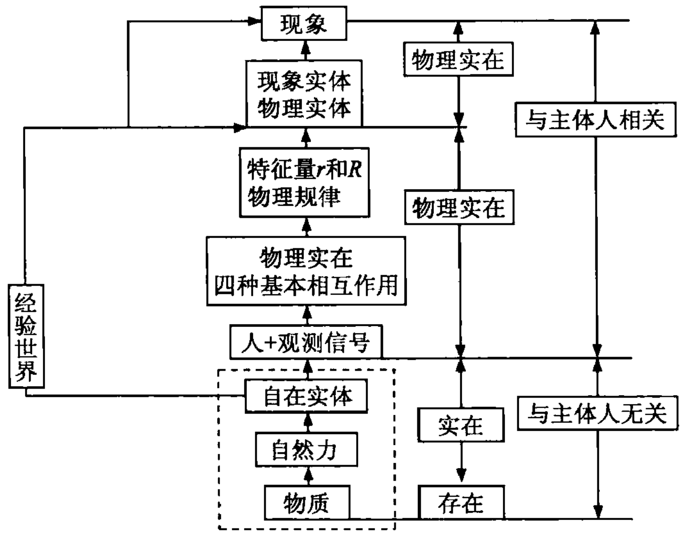


图 3.1　人类认识世界的逻辑层次图

现象，而丢掉了自在实体。前者忽视了观察信号对自在实体在时空显现上的影响，后者则是忘记了观察信号没有作用对象，现象不可能出现的道理，显然两者都是片面的。我们的目的是取二者之长，去二者之短，建立一个合理包容二者的综合理论，这意味着辩证地重构康德批判哲学的现代物理图景。

自然界中有两类基本粒子——费米子和玻色子，玻色子是传递相互作用的粒子。基本相互作用是在交换玻色子中实现的。与抽象的关系不同，基本相互作用仍然体现为物质的交换；同样，与抽象的关系实在论不同，相互作用建构实在论中物质仍然是第一性的。

基本相互作用是通过交换玻色子实现的，玻色子是物质的一种表现形式。光是玻色子，它传递电磁相互作用。在人与自然的关系中，人类认知实在性的过程是物质作用的过程。将物质的相互作用过程抽掉，变成抽象的关系，也正是这种抽象，让关系实在从“虚无”的逻辑起点出发，为量子对象不可追踪铺设哲学基础。

相互作用是建立关系的基础，但相互作用并不等于关系。相互作用实在与关系实在有联系更有重要区别。关系实在通过关系的抽象化，并认为关系第一性，在不经意中抽掉的正是唯物主义认识论的

内核——物质的第一性，抽掉的是现象、现象实体背后的本体。这对唯物主义认识论无异于釜底抽薪。在相互作用建构实在论中，狭义相互作用原理向广义相互作用原理的过渡，不是物质第一性向关系第一性的转变，而是自在实体向现象实体的转换。在我们看来，关系实在实际指的是现象实体的实在性。不是关系实在包含了相互作用实在，而是关系实在只停留在现象实体认识层次。现象实体是开放的，关系实在的开放性，体现为现象实体的开放性。关系实在是片面放大经验关系的产物。

（二）狭义相互作用原理与物体的时空形象

自然界中一切物体在时空中的形象都是由物质间的相互作用形成的，大到宇宙星球，小到微观世界的原子、电子均不例外。物体间的相互作用性质是有区别的，引力、电磁力、强力、弱力的性质就各不相同，相互作用的性质不同，大小相异，由相互作用形成的物体的时空形象也就会不同。形成地球的分子、原子、电子，形成原子核的质子、中子，形成质子、中子的夸克，由于它们之间相互作用性质和大小的区别，由其形成的物体在时空中的形象及运动状态也是各有区别的。具体体现在描述它们的“状态方程”及“解”的区别上。地球是球形的，绕太阳运动，形成地球形状及其运动状态的是长程力的引力。没有引力，地球在时空中的形象及其运动规律无以形成。地球的半径 r 及由此形成的球面曲率 $R(R=1/r)$，表征地球在引力作用下自身在时空中的形象特征。地球的动量、能量及绕太阳运动的轨道，可体现地球绕太阳运动的状态，决定轨道运动的方程则称其为地球运动的状态方程。与此相对应，我们称 r 为物体在时空中的特征半径，R 则称为与物体联系的特征曲面的曲率，r、R 表征了物体自身的时空形象，状态方程的解则表征物体运动的具体状态。

自然界中的基本相互作用力，我们统称其为“自然力”。它们的存在与人类是否存在无关。“本体”是物质在基本相互作用中形成的“形象”。并且，相互作用的性质不同，“形象”也不同，它是“人”的意识以外的东西，人类不去观测它，它照样存在，但不知道它是什么。

但是，我们认识的自然现象，及由此总结归纳的一切自然规律，还依赖于人类使用的观测信号。“物体”所受的相互作用不同，观测信号不同，一般说来，在时空中表现出来的形象是有区别的，包括表

征“物体”的特征量 r、R 及其运动方程的变化。不观测，则什么形象（现象）也不知道。物体在时空中的形象和运动规律与观测信号的性质相关。

月球在天空，在自然力的作用下，有其自身的形状和运动状态，与我们看不看它无关。但是，如果没有观测信号光，或者我们根本不去观测它，我们是无论如何也不会知道月亮的形状及运动规律的。说“月亮不看它时，它就不存在”，按照朴素直观的理解，那似乎是典型的反实在论观点，因为按照实在论的观点，决不能说自在实体不存在。因此，正确地说应该是“月球没人看它时，作为月亮不存在”。“月亮在没有人看它的时候，作为月球仍然存在”。[6]我们认为作为现象实体的月亮有时空形象，但人类如果不去观测作为自在实体的月球，就永远不会知道它的形象的！这并不能导致不可知论。因为，人类可以通过“观察”将“自在实体”转化成“现象实体”进行认识，只有“现象实体”对人类才有实际意义。总之，我们观测到的现象（或现象实体）是基本自然力作用产生的本体与观测信号作用的综合产物。不借助观测信号作用，人们就不知道本体是什么。从哲学的角度来说，“自在实体”、“现象实体”与“现象”这三者之间的关系是既不能直接混同又不能割裂开来的。“现象实体”包含有一个科学的认知过程。

由此，我们总结出狭义相互作用原理的完整表述：

自然界中一切物体在时空中的形象和状态都是由物质间的相互作用形成的，既包括基本自然力作用，也包括人类观测世界使用的观测信号作用。相互作用的变化，必然伴随理论结构的变化。

对物体的受力进行具体分析，发现物体的受力可分为内力和外力两大类。当内力作用等于零时，在一般情况下物质就无法凝聚。物质无法凝聚，组成“物体”的一定物质散布于整个空间，物质的平均密度等于零，那就等于什么也看不见，即什么也没有，当然也就无所谓物体的时空形象。如果我们用时空特征量 r（曲率半径）和 R（曲率）（不管是什么相互作用形成的）表征“物体”在时空中的形象，那么，由于此时 $r=\infty, R=0$，则与“物体”对应的，表征“物体”形象的特征曲面（时空特征）是一平面。可见，人类观念中的“平面”，若与物体的相互作用联系在一起，“几何”就与“物理”及“物体”时空特征有了有机的联系。也就是说，数学中的平面与“物体”没有“时空中的形

象”，光学作用效应为零和物质的平均密度等于零等概念联系在一起。更深刻地说，那就是内力不存，“本体”无依。这就是本体论哲学认定，不存在没有相互作用的“物体”的根本原因。

但物理上物体还有另一类受力状态，那就是外力。物理学指出，当“物体”有内力，但无外力或外力作用之和等于零时，“物体”处于静止或匀速直线运动状态。并规定建在静止或匀速直线运动物体之上的时空坐标是均匀平直时空。物体不受外力，其中包括观测信号作用也没有，理论上讲，人们根本就无法认识它。没有办法认识它，概念上是一个“无”，“无”是“零”的起源。这就是人类约定建在“静止”或“匀速直线运动”的物体上的时空坐标系是平直时空的精神实质。平直时空还是体现一个理想化的、没有相互作用的世界的特征，而这种特征用时空的均匀性来说明。牛顿的绝对时空就是一个均匀平直时空，绝对时空是一个没有相互作用的寂静世界。这与没有内力作用，约定与“物体”联系的特征曲面是平面在逻辑规定上是一致的。真空既可以是真正的“无”(如无内力作用的情况)，也可以是“有”中的“无”(有内力而无外力或外力作用之和为零)，而后者只要相应的条件(一定的外部相互作用)存在，即可“无”中生“有”。相互作用使空间的均匀性遭到破坏，“物”就从其中突现出来，这正是中国古代道教哲学的逻辑依据，也是量子场论中粒子在真空中产生与湮灭的哲学基础。

总之，物体的时空特征量 $R=0(r=\infty)$(平面)，与匀速运动坐标系“时空平直”等价，都表示没有相互作用，对物质或本体无法认知。要使物质或本体被我们认识，在时空中表现出“有形结构”，就必须施以相互作用(包括观测信号作用)，让“物质”和“本体”呈现出人类认识的时空结构。由此，我们得到推论一：

没有相互作用，“物质”无以形成被观测的时空形象。

“物质”之所以在某处形成时空形象，是因为“物质”在该处受到力的作用(包括观测信号作用)，使形成的物体的动量、能量发生了变化，并伴之以一定的变化过程，改变了与物体联系的时空特征量 r、R 或建在物体之上的坐标系的时空均匀性。物体在 A 处出现，既可以是 A 处“物体”自身的空间结构发生了变化(由 $R=0$ 到 $R\neq0$)，也可以是与物体联系的坐标系的时空均匀性发生了变化，显示了物体的

存在。两者既与内力相联系，也与外力相联系。在微观世界，则通过物质波波长 λ_n 除以 2π——特征半径 r_n 的倒数，即曲率 $R_n = p_n/\hbar$ 形成的"空间结构"，体现"微观客体"的可观测程度。是相互作用，包括观测信号光的作用，使我们得以认识一个客体在时空中的特有存在形式(或特有的时空结构)。

力的作用能够改变与物体联系的"时空结构"，显示"物体"的存在，而"物体"所在处"时空结构"的变化，反过来又可影响其他物体的运动状态，表现出某种运动趋势，体现某种力的作用特征，表现出物体所在处存在一种场的作用。场的相互作用与物体建立的"时空结构"的变化是一个问题的两个方面，加速场与均匀引力场等效是广义相对论的前提假设，正好体现广义相对论与相互作用原理的内在联系。于是我们得到推论二：

时空变化之所在，即为"物体"之所在，也是场源之所在。

有了上述狭义相互作用原理及推论，现在我们可以来回顾和讨论牛顿力学、相对论力学和量子力学中物体时空形象和状态描述的哲学基础了。

按照前面的分析，物体时空形象的形成，其动因既包括产生"本体"的基本相互作用(自然力)，也包括观测使用的观测信号作用。自然界中的任何物体如果不做理论抽象，显然都不会是质点，都有与相互作用相联系的特征量 r 和 R。观测信号对物体在时空中的形象也应有影响。但牛顿力学都把物体简化为质点，质点无大小，没有几何形状，物体自身无形象，加上牛顿力学中观测信号作用速度无穷大，无穷大的信号速度无法区分物体上不同的时空点。因此，牛顿力学中，观测信号也就无法判别和影响物体因运动而引起的时空形象的变化。这等于忽略了观测信号作用对物体时空形象的影响。坐标系是建在物体(参照物)之上的，物体(参照物)的时空特征就是坐标系的时空特征。忽略观测信号对运动物体(参照物)时空形象的影响，也就是忽略观测信号对坐标系的时空特性的影响。所以牛顿力学中时空是绝对的，与物体的运动状态无关。从不计观测信号作用对"物体"时空特征的影响角度看，牛顿力学是"现象实体"可以直接等同于"自在实体"的力学。"现象实体"的时空特征也就被看作"本体"的时空特征。这是一种过分简单化、理想化了的近似假说。日常生活中，

人类对自然现象的许多认识与思考都有意无意根植于这一自然哲学原理。

库恩的“范式不可通约”，把“现象实体”误为“本体”的错误思维，其哲学根源可能也来源于此。

围绕质点的意义，牛顿力学给出了逻辑一致的假设。这就是：(1)信号作用速度无穷大。因为作用在物体上任何一处的信号都是同时到达，无法区分不同的时空点，所以“物体”简化为质点。(2)质点的内能密度无穷大，能量密度无穷大，预示物体的内力作用无穷大。因此，无穷大的作用对应牛顿力学质点的含义。(3)牛顿力学是推论二的极限理论。物体的时空特征 r、R 取极值。特征半径 $r=0$，特征曲面的曲率 $R=\infty$。一切自然定律在此处失效。物理学中用奇点表示粒子，奇点物理性质的自然哲学基础应源于此。

相对论力学则不同。相对论力学否定了光速无穷大特性，承认光速有限，实际上是否定了物体的点粒子特性。爱因斯坦的火车对时实验，即是最好的说明，火车就不是质点。否定了物体的点粒子特性，也就是承认观测信号作用对物体的时空形象有影响。相对论的光信号对时及光速的有限性对时空特性的影响，正是源于这样的新的自然哲学原理。当然，相对论物理学中物体最后还是变成了质点，但那是在将观测信号作用对物体(兼作参照物)时空形象的影响，归结为坐标系的时空属性之后才办到的。物体成了质点(坐标系建于质点之上)，时空形象无变化，但与物体(参照物)联系的坐标系的时空却在变化。这种抽象处理，体现了爱因斯坦的超常智慧，是空间即物质广延性哲学思想的具体化。相对论力学是比牛顿力学更精确的力学，在对现象的描述中，它既考虑了牛顿力学中的基本相互作用，又考虑了观测信号作用。但是必须指出，相对论力学考虑观测信号(光)对物体时空形象的影响时，不动摇基本相互作用对物体时空形象的定位，而且引力和光的作用被看作是连续的，形成了时空的连续性。电磁力作用对时空的影响可以转换成引力的变化对时空的影响。本书的后继章节将作深入讨论。由于时空特征是相互作用的产物，因而连续的作用保证了时空的连续性。这是宏观低速和宏观高速世界的特征，在微观世界情况则另当别论。

在微观世界，光子与电子的作用是不连续的，吸收与释放是一份

一份的。因此，电子的时空特征也表现出不连续性。间断的相互作用造成了形态突变区的存在。光子和电子之间相互作用的大小和方向当然也是可以变化的。因此，由相互作用形成的电子的时空特征量 r 和 R 也是变化的，体现出不同时空点上曲率 R 的波动。但每个能级有一个基本的最大值，出现在波函数的振幅中，我们称其为基准曲率。按照我们的新的理解方式，这就是电子波的本质所在。电子波反映的是电子运动过程中，通过光学现象表现的“自身空间结构”（“表面曲率”）的变化。我们还要证明，“空间结构”——“形”的变化与点粒子出现的概率的变化是可以相互转换的。曲率解释可以包容概率解释，并弥补了概率解释中对“形”的缺失。

第二节 现象实体的三种认知进路和人类认识自然的逻辑通式

一、现象实体的三种认知进路

哲学所称的“感觉表象”，不涉及感觉表象产生的科学机制。两百年前人们恐怕还无法深入研究“感觉表象”的科学机制问题。但今天的情况却不同，现代物理学、现代生物生理学、现代脑科学、现代神经科学及计算机科学的迅速发展，为研究“感觉表象”的科学机制提供了基础。就我们的研究，“现象实体”至少有三种不同的认知途径。

第一，“自在实体”通过光等中介传媒直接作用于人的感官（主要是视觉系统），在人的大脑中引起感觉表象，建构、认知“现象实体”。例如，通过光我们看到月亮、太阳是圆的。月亮、太阳的形象，就是通过光直接作用于我们的眼睛，然后由大脑中的神经系统综合建构出来的。这就是一种认知。现代脑科学与现代神经科学已为这种认知的建构特性做了充分的科学研究。取出人观看苹果的脑波信息，我们可以让人看到的苹果形象在计算机屏幕上重现。我们看到的月亮、太阳、苹果不是本体，而是本体通过传媒（光）和人的眼—脑系统共同作用形成的“现象实体”。“现象实体”是系统的、稳定的“感觉表象”。

第二，“自在实体”向“现象实体”的转换，不能由人的感官和大脑

直接认知，而是通过感官的延伸——显微镜、望远镜等在我们的大脑中形成被观察物的形象。例如，微生物、细胞、分子、遥远的星球等。当然，这种方式形成的视觉表象，一方面和第一种情况一样，最终都离不开人眼一脑的直接建构；但另一方面，仪器的原理、设计却离不开人类已有的知识、理论和已经建立起来的逻辑体系，感觉表象又与人的理性有一定的联系。

第三，“现象实体”还有一种间接认知方式。那就是人不能直接感觉，而是自然现象通过人的观察，由已有的经验、知识、理论和逻辑基础，为研究对象建构“形象”。这种“形象”不是精神，它有实体依托，亦有现象表现，是物理实在，是物理学的研究对象。在微观世界，电子不但肉眼看不到，就连再高倍的显微镜也看不到。我们对电子等微观客体形体的认知，只能凭现象观察、经验、知识、理论和相应的逻辑推理来进行建构。我们曾想像过原子像颗葡萄干，电子像沙粒镶嵌其中，后来发现不对；接着又想像成形状不变的小球，绕原子核旋转，后来又发现在原子世界仍不能成立。在原子世界电子是一个波粒二象性的统一体。波粒二象性的统一是个什么样的实体，电子的形状可变？反正，这个该死的电子至今仍在折磨人类的思维。当然，也有人索性把电子的实体性丢掉，变成由经验所构建的一堆关系的称谓，关系的“纽结”本身反倒没有了，只剩下一堆关系，那电子是个什么东西？电子什么都不是！这就是强化关系，虚化“纽结”的结果，是反科学实在论者的出发点。显然，这个想法不能为人们所接受，尤其是不为坚持实在论的物理学家所接受。看来，建构一个符合客观实际的电子“现象实体”仍是人们追求的目标。“建构”强调的是人的认知过程。

人类通过自身的感官或感官的延伸建构的“现象实体”是客观实在，人类通过现象观察、经验、知识、理论和逻辑推理建构的“现象实体”亦是客观实在。月亮、太阳、遥远的星球是实在的，微生物、细胞、分子也是实在的，量子力学中具有波粒二象性的电子等微观客体还是实在的。不过电子“现象实体”需要通过前述第三种方式去建构。

其实，人类对地球形状的认知，历史上用的也是第三种方法。在古希腊就曾有人认为球形的地球最合理，但站在地球上，人只能感觉到一个平面地球。球形地球是通过绕圈探行后回到原地及海平面上

先看到船的桅杆得到证实的。这是先有推理建构，而后证实。当然，我们现在可以在宇宙飞船上直接看到球形地球。但那是科学技术进步的结果。显然，由经验、知识、理论和逻辑推理间接认知的“现象实体”同样具有实在性，人类对电子的认知也应如此。必须指出，我们不是建构“自在实体”(本体)，而是建构“自在实体”的“形”。“自在实体”有了被认知的“形象”，才转化成“现象实体”。因此，我们建构的是“现象实体”。“本体”是不能建构的，而且“现象实体”不等于“现象”。“现象实体”是物理哲学中的概念。

牛顿力学中，现象实体的“形”在讨论的问题中，均被认为对讨论的问题没有影响，可以忽略不计。物理学描述的对象——物理实体抽象成了质点。物理实体是实在的，牛顿力学中质点就代表了物理实在。在相对论力学中，质点仍代表了物理实在，广义相对论中，广域分布的场也是物理实在，时间空间受物质分布影响，也以几何场的形式成为一种物理实在。量子力学中的电子等微观客体，物理实在的表现形式是什么？还能是“形”忽略不计的质点吗？问题在于，我们连电子的“形状”是什么现在还十分迷茫，如果连形状是什么都不知道，就把“形”忽略掉了，对电子的认知，能不出问题吗？

人类对宏观现实世界的认知基于宏观连续作用，恐怕应是共识。人脑通过光的连续作用而辨识宏观的“现象实体”，就是一个连续的图像。其实人对非连续发光的适应能力是很差的，电影胶片，如果每分钟少于 24 幅，就不能形成连续的画面。在原子世界，电子在能级跃迁中给出的是非连续的光谱，用非连续的光叫大脑直接建构原子中电子的形象是强其所难。人的大脑还没有这个能力。更何况，原子中的电子除能级量子数之外，还有角量子数、磁量子数和自旋量子数等不连续概念($h\neq0$)。说电子是一个大小不变的光滑小球，并可抽象成质点，那纯粹是根据宏观连续作用($h=0$)所做出的经典想像。卢瑟福的原子模型，就在这种想像中碰了钉子。

微观世界的作用是非连续的，人脑无力对非连续发光的客体直接建构其形象，完成“本体”到“现象实体”的转化。但人类必须完成这一转化，否则对原子中的电子就不能做到完全的认知。在前述“自在实体”到“现象实体”的三种转化途径中，只有第三种可用。对微观客体的认知，我们必须通过微观客体给出的光学现象，由经验、知识、

理论和相应的逻辑基础进行形体建构。被建构的电子“现象实体”，必须具有波粒二重属性。它不是精神而是地地道道的物理实在。因为这个物理实在，可以通过它表现出的光学现象得以还原证实。说得具体些，也就是由第三种方法建构的，与原子中电子等微观客体对应的“现象实体”，通过量子测量(连续作用的介入)，可以呈现出客体的宏观经典粒子属性。有报道表明，人类正在对原子中电子的跃迁做出实验测量。

应该引起物理学家注意，即使将来成功测量到了能级跃迁中的电子，那也是连续作用介入后呈现出的电子，它不应等同于测量前非连续作用中的那个电子。测量让“电子”的形态发生了变化。

二、原子中电子“形象”的建构及物质波的物理意义

原子中电子在能级跃迁中放出光子，光子的能量 $E_{光}=h\nu=E_2-E_1$，E_2、E_1 是电子在能级 2 和 1 上的能量，ν 是光的频率。光子的能量直接体现出电子能量、动量的改变。电子的动量与电子的德布罗意物质波波长有直接的关系，而波长与空间概念相关。物理学上就常用康普顿波长除以 2π($\lambda\!\!\!^{-}_0=\lambda_0/2\pi=r_0$)作为静态粒子的特征长度。我们的研究表明，将这个特征长度视为静态粒子的分布半径是有实验依据的。美国实验物理学家霍夫斯塔特对中子、质子分布半径的实验检验，[7]及其他人对电子分布半径的测试，实验数据与特征长度就符合得相当好。[8]可见用波长建构电子的“形”是有实验依据的(见附录 2)。

静态电子不是原子中的电子。静态粒子的特征长度不适用。原子中的电子在不停地运动。电子从一个能级跃迁到另一个能级，我们看到的是光的频率和强度，是不连续的谱线，不连续的光谱不能给大脑建立一个连续的电子形象。但原子中电子的德布罗意物质波波长有空间概念。类似地，我们试用原子中的德布罗意物质波波长 λ_n 除以 2π($\lambda_n/2\pi=\lambda\!\!\!^{-}_n$)，作为原子中能级 n 上电子的基准曲率半径 r_n。氢原子中，这个半径 r_n 刚好可以表述成：$r_n=na_0$，n 是能级量子数，a_0 是玻尔半径，$R_n=1/r_n$ 是相位圆的曲率，氢原子及其他物质波波函数的振幅中均可分离出 $1/r_n$ 这一曲率因子。每一个能级有一个基准曲率 R_n 与电子对应，每一个时空点有一个与电子对应的曲率

在变化。所以我们认为物质波是曲率波。曲率的大小表示电子的粒子性，曲率的变化表示电子的波动性。[9]波动性和粒子性在原子世界有了和谐的统一。

原子中电子越靠近原子核，曲率 R_n 越大，能级跃迁时发射的光子的频率越高；电子越远离原子核，曲率 R_n 越小，能级跃迁时发射的光子的频率越低。原子中电子越靠近原子核，曲率 R_n 越大，“形”越小，在“形”内找到点电子的概率越高，电子跃迁概率越高，光越强；电子越远离原子核，曲率 R_n 越小，“形”越大，“形”内找到点粒子的概率越小，电子跃迁概率越低，光越弱。曲率解释充分利用了光在人类建立客体“形”中的作用，我们把这叫“光形转换”；曲率解释同样利用“形”与质点之间的关系，建立了概率解释与曲率解释之间的对应连接，我们称其为“形点转换”。曲率解释可以包容概率解释。但我们可以证明原子中，我们用波长为电子建构的“形”在原子深处不可忽略，失去了宏观质点抽象的条件[10]。如果非要把原子中的电子抽象成质点，点电子的位置就会有分布误差，误差范围就是电子“形”的展布半径。“点”电子有了新的性质，这就是“质点”在其“形”内的不确定性。而且质点是虚的，波是实的，表现为动量决定的空间特征量的变化。原子世界中，曲率波和虚质点共同组成了量子力学的描述对象——电子的物理实在。

玻尔用互补原理说明波粒的统一性。后人用生动且富有哲理的图像图解说明。从图像的黑色部分看，是两个人面对面，从两个面孔的空白部分看是一个花瓶。到底是两个面孔面对面，还是一个花瓶。都是，又都不是。黑白交界处的“波动”曲线正好表示了人面和花瓶。这个“波”是人面花瓶波。两个互不相关的东西有了相关性。

但在量子力学曲率解释中，这个图案的黑白交界线被物质波波长绕成的相位圆的圆周所代替。从黑色部分看，圆的曲率表示曲线的弯曲程度，代表微观客体的“形”象，从圆内白色部分看，黑白交界线表示在圆内找到虚质点的概率。“形”小，曲率大，找到的概率大；“形”大，曲率小，找到的概率小。粒子性与波动性在黑白交界线上得到了理想的统一表达。

不过我们还想说明，人类对“现象实体”、“形”的识别，还有赖于“现象实体”与“现象实体”存在的环境，看其是否能与背景空间分离。

在宏观连续作用的世界，客体与背景空间的分离让人的眼—脑系统有很好的形体分辨与建构能力。在微观世界，如果“形”在讨论的原子问题中不能忽略，表明客体与环境难以分离。这时讨论客体的运动，就难以用从空间中分离出来的形体抽象成的质点进行描述，而必须改用客体在不同时空点上表现出的时空特征进行描述，这就是量子力学中波函数的物理意义。它的客观实在性是毫无疑义的。

三、人类认识自然的逻辑通式

人类对自然界的认识，离不开主体、客体（本体）、观测信号三个基本要素。主体、客体（本体）、观测信号与“现象”（物体的时空特征）之间的关系，构成了人类认识自然的逻辑基础。

但是，在讨论人类认识自然的逻辑基础之前，我们还得根据前述的相互作用原理，对一些重要概念作进一步的明析。

①本体（客体）——是一种与自然力相关与主体无关的客观实在。如果人类不通过一定的观测信号去观测，人类将不知道“本体”是什么。

②主体——人是认识自然和社会的主体。没有主体，与人类相关的“价值体系”将失去意义。

③“现象”——泛指现象、现象实体的时空特征。

④观测信号——没有相互作用的物体是不存在的。目前人类发现的基本相互作用有四种，即引力、电磁力、强力、弱力。人类用以观测本体的信号，目前就是上述四种，而最基本、最常用的是电磁信号。没有观测信号，人类无法将本体转化为被认识的自然现象。

⑤意义——特指人类对自然现象评价的价值体系。没有主体，任何自然现象的价值还原为零，也即意义为零。

明晰了上述五个基本概念之后，人类认识自然的逻辑通式即可建立，它表现为：

$$\text{主体}+\text{观测信号}+\text{本体（客体）}=\text{“现象”}\cdot\text{意义}$$

或

$$A+B+C=D\cdot E \tag{3.1}$$

这里，A——主体，B——观测信号，C——本体（观测对象），D——“现象”，E——意义，$\cdot$——乘号（参看本章第一小节的解释）。等式的左边是人类认识自然的三个基本要素，等式的右边是认识的

结果。

①若 B(观测信号)=0,则 D(“现象”)=0

即 $$A(\text{主体})+C(\text{本体})=0 \tag{3.2}$$

上式表明,主体人离开了观测信号,对自然现象将无法认知,本体无法转化为人所认识的现象、现象实体,即认识对象——“现象”=0,这是很容易理解的。试想,如果人类处在一个信息全无的“黑暗”世界,我们还能了解到世界上的什么呢?本体无法转化为被认识的“现象实体”,本体虽在,但“现象”全无。这就是“现象”为零的意义。

②A(主体)=0,则 D(“现象”)=0,E(意义)=0,

即 $$B(\text{观测信号})+C(\text{本体})=0 \tag{3.3}$$

(3.3)式表明,如果自然界失去了认识的主体——人,那么,自然界的本体,除了无法转化为人认识的“现象”之外,自然界的一切由人定义的价值体系也将失去意义,这即是 $D=0$,$E=0$,这很像哲学家尼采对人的价值观的认识。离开了人类观测的存在,只能是抽象的存在,这个存在只有哲学意义,而无现实意义。

③C(本体)=0,则 D(“现象”)=0

即 $$A(\text{主体})+B(\text{观测信号})=0 \tag{3.4}$$

(3.4)式表明,只有观测信号作用于本体,才能得到一个对人类有价值的实际存在——现象、现象实体。没有本体,观测信号没有作用的对象,则“现象”=0。其实,如果(3.4)式中的本体不存在,主体和观测信号也就不存在。因为主体人和观测信号本质上也是由本体构成的,本体不存在,则世界不存在,哪有人和观测信号呢?

唯心主义者认为意识决定物质。意识第一性,物质第二性。(3.4)式还可以帮助我们解析唯心主义认识论的逻辑起源,指出其认识的偏差始于何处。

意识是主体所具有的,而主体从物质属性上都可归于本体。本体没有了,即产生意识的主体——人没有了,何来人的意识?唯心主义的错误在于,它不了解(或不愿意承认)主体人本身也是物质本体构成的。本体的消失,思维过程不存在,人的意识也自然消失。世界都不存在,何来意识决定物质?

当我们认识到思维(意识)本身也具有物质属性的时候,世界将

完全统一于物质。思维(意识)与物质的关系不再是谁决定谁的问题,而是与思维(意识)对应的这种物质到底是如何产生的。我们应当进一步研究的是人脑中与意识对应的这种物质产生的物理化学过程。这是当今世界脑科学和思维科学研究的课题。

可见,人类认识自然的三要素缺一不可,人类要全面正确的认识世界,必须是 $A\neq0$,$B\neq0$,$C\neq0$,最后才能保证 $D\cdot E\neq0$,这就是人类正确认识世界——逻辑通式(3.1)必须具备的前提条件。

牛顿力学是本体=现象实体的力学,它一方面忽视了主体人在认识自然现象中的作用,另一方面忽略了人使用观测信号时,其作用对被观测对象的影响。牛顿力学认识论的逻辑通式是

本体=现象实体

即现象实体的时空特征就是本体的时空特征,这显然是不全面的。

相对论力学考虑到了观测信号作用对“本体”在时空显现中的影响,但对于人的主体地位却并不确定。如果主体是非人的其他动物,则其理论结构会发生相应的变化,即体现为观测信号的变化或极限速度 c 的变化。人使用的观测信号(对时信号)是光,而其他非人的动物使用的可能是其他通讯信号。例如蝙蝠使用的是声波,其理论结构和“现象”、“现象实体”的描述则完全不同于人类。历史表明,人类可以将“另类”的认知,转化为人类的认知,这是人之所以为人的最可贵的地方。

量子力学,尤其是哥本哈根学派的正统量子力学,对微观世界的描述,本来不但考虑到了观测信号——光的作用,而且在量子测量理论中,还考虑了量子概率向宏观经典概率转化的作用机制问题。应该说量子力学的建立过程是符合人类认识自然的逻辑通式的。可惜的是,它一方面把波函数描述的对象,一味地理解成了“量子概率”,而不是电子在时空中的波动形象特征;另一方面,它把观测信号对客体时空形象的影响,直接归为思维对客体的影响。纠正这一认识偏差,正是“量子力学曲率解释”的任务。

应该注意,我们强调人在认识客观世界中的主体地位作用,并不是说人的主观意识对本体有什么干扰作用,而是说人在认识客观世界——“本体”时,离不开观测信号作用对本体的影响,而意识——人

脑的活动本身对客体(本体)的运动规律并没有什么干扰作用,而只是对客观世界的能动反映,并在观察信号的作用下伴随有相应的物理、化学、生理机制发生。关于这一点,海森伯说得很透彻:"量子论并不包含真正的主观特征,它并不引进物理学家的精神作为原子事件的一部分。"从辩证法观点看,作为观测者的人本来就是自然(被观测者)不可分割的一部分,人只能处在自然之中看自然,必须使用自然信息作为观察信号。这样,用内在化观点看,不仅自在实体间的相互作用不可避免,而且观测者与自在实体间的相互作用也是不可或缺的。总而言之,我们强调人对自然的认识是本体与观测信号相互作用的综合产物,不仅完全合乎唯物论,而且完全合乎辩证法。

第三节 存在、实在及现象实体的开放性

广义相互作用原理指出,每一事物通过其自身体现出联系的普遍性,而又通过联系的普遍性表明自身的存在。"实体是它自身的原因","相互作用是事物的终极原因",这表明事物是在相互联系、相互作用中表明自身的实在性的。

狭义相互作用原理则试图把人类对自然的认识更加科学化、具体化,试图将恩格斯、康德、马赫、笛卡儿等哲学家的哲学思想好的部分集中起来与现代科学融为一体,从而展现人类认识自然的科学进路。我们清晰地看到,牛顿力学、相对论力学、量子力学都是在人类一定的认识层次上,通过相互作用(包括观察信号作用)描述客观世界,揭示客观世界的"实在性"及其运动规律的科学理论。

"物质是我们感觉到的客观实在。"这里,列宁所说的"客观实在"物,就是我们所指的"现象实体"或"物理实在"。人如何"感觉到"?当然有不同的方法。一是凭我们的感官,二是凭感官的延伸——仪器,三是通过现象由推理认知。但不管是感官直接感受,还是仪器间接感受,亦或是通过现象推理,要"感觉"到观察对象是一个客观实在,实在是离不开相互作用信息的交流。我们看到山川、湖泊、星星、月亮、房舍、村庄,这是借助光的作用才感觉到的。人在地面行走,感知到地面是一个"客观实在"是因为有引力的吸引和脚与地面的接触摩擦作用。我们向一堵墙走去,如果人与墙没有直接的阻碍作用,人

将穿墙而过，我们将无法感知墙的“客观实在性”。卢瑟福用 α 粒子轰击原子，如果没有原子核与 α 粒子之间的相互作用，使 α 粒子散射，可以想像，人类至今也不会知道原子的结构为何物。一束 α 粒子打进靶内，如入无“人”之境，那么人类如何“感觉”到靶的“客观实在性”呢？也许有人会说，靶是可以用手“摸”到的。请注意，这“摸”就是引进了相互作用。因此，我们可以说，物体间相互作用愈强，感知物质的“客观实在性”越易；相互作用越弱，感知物质的“客观实在性”越难；没有相互作用就无法感知物质的“客观实在性”。物质的“客观实在性”是通过相互作用感知的，或者说物质的“客观实在性”是通过相互作用呈现的。

“现象实体”的物理实在性是通过人的观察作用所给出的呈现。

上面的论述是人在“感知”。对于一个客观实在，应该是不以人的主观认识为转移的。那么，物质之间是如何“感知”客观实在的呢？运动是物质的基本属性，物质间的相互作用是物质间“感知”“实在”的友谊的“天使”。“物质总是作为力的源泉而作用于其他物质并由此确证它的存在”。[11]爱因斯坦这里所说的“力”其实就是一种场。电磁作用能使电荷之间感知到实在性，“吸引”、“排斥”是“感知”物质实在性的表现形式。引力场能使有质量的物体之间感知到彼此的实在性，吸引是彼此之间“感知”实在的表现形式。弱力本质上与电磁力同源，它是弱电力的另一种表现形式，强相互作用是核子之间“感知”实在的力。一个不参与强相互作用的粒子，用强场去探测会全然无知，就像用电磁场去探测中子，如果中子不是两种电性物质的中和，则不能感知中子为何物一样。“场”只能识别自己的“同胞兄弟”，而对异姓姐妹却全然无知。我们不能用彼此之间不发生相互作用的场物质去“感知”对方的“客观实在性”。彼此不发生相互作用是无法感知实在的，不管是人类与自然，还是自然本身都是一样。一个完全不运动的世界，物质间传递相互作用的场物质消失，物体之间将无法“感知”彼此的实在性。没有实在性的世界是一个全“无”的世界。这等于说，毫无相互作用的世界根本就不“存在”。这又从另一个侧面证明了运动是物质的基本属性，世界是由运动着的物质组成的，绝对不动的物体根本就不存在的哲学原理。

离开人的观察，想像中物质间相互作用呈现的“实在性”，是我们

定义的“实在”，它与“本体”相对应。本体的“实在性”通过现象实体的实在性得到认识。

物质的运动是在时空中运动，物质的存在也是在时空中存在，玻色子场是物质间彼此感知客观实在的“天使”。物质的运动状态不同，场的性质不同，人们“感知”的物质的存在形式—实在性也就不同。黑夜里我们用红光去照射物体，物体发红光，呈现红色；我们用紫光去照射物体，物体发紫光，呈现紫色。用弱相互作用场去照射，物体将全然无“知觉”。场物质全部穿透物体就无法感知物体的“客观实在性”。物体到底是红色的，还是紫色的，还是不“存在”？只是所使用的感知对方“存在”的场信息不同，结果不同而已。因此，我们认识的物体在时空中的形象肯定带有“感知场的偏见”，只是有些我们知道，而有些不知道而已。我们也许无法说清楚物体最终还会有什么，但我们可以说清楚物体现在是什么！一切物质的客观实在性都是通过相互作用感知的。相互作用是多样的，实在性是开放的。随着探测信息的转换，我们可以更多地认识物质的各种各样的尚未发现的特性(这就有别于不可知论)。我们还能够发现过去认为“不存在”的东西，而过去认为存在的东西，在一定的条件下也可以不翼而飞。这完全是“感知实在”的相互作用场的魅力。人类通过弱相互作用认识中微子的存在就是一个最好的例证。一个物体是否“存在”，以及怎样“存在”，或者说物体能否被感知，及感知的形象是什么，与我们使用的探测场信息有关。如果用“曲率”表示物体的形象，则“曲率”会随场的作用的变化而改变。目前人类能够使用的“感知场”有引力场(感知质量 m)，电磁场(感知电荷 q)，强相互作用场(感知“强荷”)，弱相互作用场(感知“弱荷”)等等。我们完全不用担心，在一种探测场中“不存在”——失去某种“实在性”的东西，其物质性会在世界上消失。辩证唯物主义的“存在—物质”是各种相互联系、相互作用辨认的“物理实在”(现象实体)的总和。

此外，相互作用原理还告诉我们，有怎样的相互作用就有怎样的理论结构。相互作用发生质的变化，理论结构也会发生质的变化。相对论力学与牛顿力学理论结构的变化，在于观测作用中，光速从无限到有限的变化；经典力学与量子力学理论结构的变化，在于能量量子的出现，在于“形”的不能忽略，在于相互作用从连续到非连续的变

化。不同的认识层次中，相互作用变了，理论结构也就变了，现象实体也就变了。本体就有了新的呈现。现象实体是可以建构的，本体不能建构。科学理论的结构是开放的。

这就是我们提出的相互作用建构实在论。“建构”体现为一种科学的认知过程，它具有开放性。

现在我们可以把人类认知自然的程式作出更详细的图解。见图(3.2)。

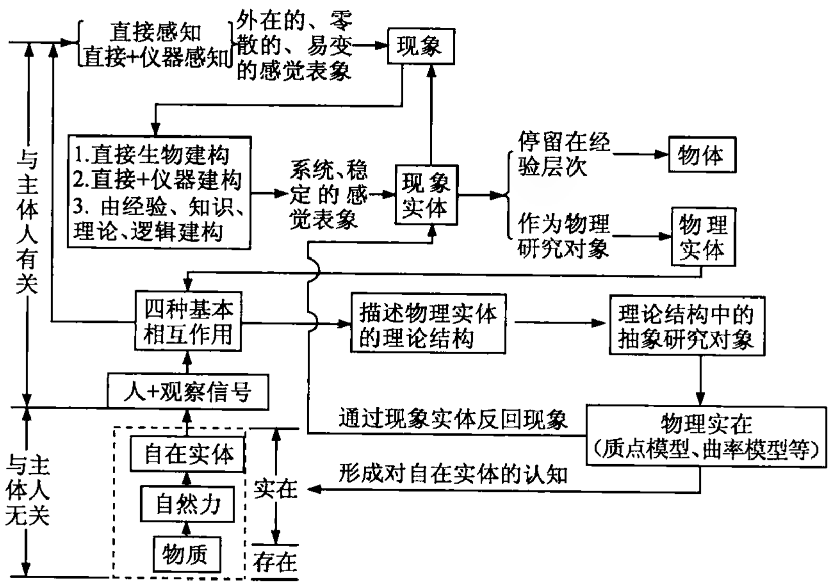


图 3.2 人类认知自然的逻辑程式图解

图解说明：人类对于本体的认知，首先观察到的是“现象”。它是外在的、零散的、易变的“感觉表象”。经人的生物建构(科学的认知过程)，形成系统的、稳定的“感觉表象”。这就是“现象实体”。“现象实体”停留在经验层次，就是日常生活中的“物体”，作为物理学研究对象，就是“物理实体”。“物理实体”在特定相互作用中的运动规律，由理论的结构来体现。而理论结构中抽象研究对象就是“物理实在”。例如：质点模型、曲率模型等都是物理实在。通过“物理实在”，我们可以认知本体。本体是不变的。相互作用的多变性，将引起现象实体的多变性、开放性。现象实体是建构的，当然物理实体也是建

构的，物理实在也是建构的。它是本体的不同呈现，通过物理实在我们既可以认知本体，也可以还原为现象。图中，“现象实体”→物理实体→相互作用→物理实体的理论结构→理论结构中的研究对象→物理实在（质点模型、曲率模型）展现了由经验、知识、理论、逻辑共同建构“感觉表象”——“现象实体”的第三种认知过程。

上述认知途径逻辑首尾相接，十分美妙。

参考文献

[1] 金吾伦.生成哲学[M].石家庄：河北大学出版社，2000：4，215.

[2] 马全民，等.哲学名词解释（上）[M].北京：人民出版社，1982：110.

[3] 冯契.哲学大辞典[M].上海：上海辞书出版社，2001：1579，1582.

[4] 康德.未来形上学导论//冯契.哲学大辞典[M].上海：上海辞书出版社，2001：710.

[5] 洪定国.物理实在论[M].北京：商务印书馆 2001：110-118.

[6] 罗嘉昌.从物质实体到关系实在[M].北京：中国社会科学出版社，1996：349-358.

[7] 费因曼，C.米勒.今天的物理学[M].叶悦，等译.北京：科学出版社，1981：168-173.

[8] 倪光炯，等.近代物理学[M].上海：上海科学技术出版社，1979：146.

[9][10] 赵国求，桂起权，等.物理学的新神曲[M].武汉：武汉出版社，2004：241-294.

[11] 阿尔伯特·爱因斯坦.物理学的进化[M].周肇威，译.武汉：上海科学技术出版社，1964：35.

Chapter 4
Macro, Microscopic Mass Point Abstract & Conversion of Function Mechanics

4.1 On the Attributes of Mass Point in Classical Mechanics & Quantum Mechanics

4.1.1 Attributes of Mass Point in Classical Mechanics [1]

4.1.1.1 Attributes of mass point in Newtonian mechanics

Materialist philosophy believes that space and time are existent forms of substances in motion. There is no space-time divorced from substances, nor substances away from space-time. According to the materialist discussion of space-time, the descriptions of motional condition of objects in physics should include the description of space-time property of the substances. Motional conditions of objects are determined by the interactions among objects, but according to the natural laws that describe motional conditions, image features of substances expressed in space-time must be discovered through the human observation. Observation needs observational signals and instruments. Presently, the human beings are able to use four field signals: ① electromagnetic field (light); ②gravitational field; ③weak force field; and ④ strong force field. Therefore, the known motional conditions of substances and image features substances expressed in space-time must be stamped with

brands of these four fields and must change with the change of effect properties, intensities, and speeds.

According to the idealized methods of physics, if the size of an object plays no function in the researched matter, or its function can be ignored, we can approximately regard the object as an ideal object of no image and size, called mass point. Generally speaking, the position where mass center of an object lies is the location of mass point.

Isaac Newton's three laws construct the basis of Newtonian mechanics, and these three laws all take mass point as the research target. We may say that, Newtonian mechanics is mass point mechanics. Mass point has no size, no to say space-time image. When the human beings observed moving objects and summarized motion laws, the changes concerning the changes of space-time features of the objects were often ignored. In Newtonian mechanics, the motional conditions of objects in space-time can only be determined by momentum of mass point, energy and its motional trace.

To determine the position of objects in relation to the reference or changes of their positions with time, a fixed coordinate system needs to be selected on the reference. Usually, a point at reference is chosen as the origin of the coordinate system. The line passing through origin and marked with length units is coordinate axes.

In Newtonian mechanics, objects are simplified as mass point; therefore, when coordinate system is constructed on the object, the mass point of the object is the origin of the coordinate system. The motions of reference, coordinate system, and mass point (origin) are equal in value. At this time, the motion of the object corresponding to the reference can also be abstracted to the motion of mass point in relation to the coordinate system.

However, any concrete object is by no means mass point. As long as the substance is not mass point, and when we observe it with certain field information, the space-time characteristics of the

substance is bound to be related to the motional conditions of the object, and to the spreding speed of the property, intensity and function of field information used in observation. While in Newtonian mechanics, when mechanic system was constructed, in abstract from reference to coordinate system, according to the principle of mass point mechanics, the geometric image of object itself and the change of the image in motion were all taken out; thus, any object became mass point and lost its space-time image. This shows that, in Newtonian mechanics, the motion and the effects of field information used in observation of space-time characteristics of objects are completely ignored. The coordinate system is constructed on objects, so to take out the motion and the effects of observational signal on space-time features of reference is to take out the motion and the effects of observational signal on space-time features of coordinate system. Therefore, the motion of the coordinate system and observational signal has no effect on space-time in Newtonian mechanics. Object can be separated from background space-time, and has no relation to it. This is also the logic requirement of Newtonian mechanical "mass point" model for space-time absoluteness. Obviously, Newtonian mechanical "mass point" far surpasses its original meaning.

It must be specially pointed out that, when Newtonian mechanics abstracts object to mass point, on one hand, mass point, representing object, has its definite momentum, energy, location and time in motion; on the other hand, mass point and space-time point coincide. Therefore, the motion of Newtonian mechanical mass point has its definite motional trace in space-time.

4.1.1.2 Mass point attributes in special theory of relativity

In special theory of relativity, Albert Einstein used electromagnetic field (light) as the field signal in observing space-time features of objects, and before the establishment of space-time system, reference was not mass point. This could be best illustrated

by Albert Einstein's "train timing" experiment.

In the "train timing" experiment, Albert Einstein supposed the length of "train" as $A'B'$, at the central point M' of which, there is an observer. The length of the corresponding ground was AB, the central point of which was M. There are four cases to be discussed as follows:

① Take train as mass point.

According to its definition, mass point has no size and A', B', M' on the train coincide; obviously, whether the train is in motion or in static state, inter-perceiving field signals need no time to pass through the train in both cases; thus, the observer M' on the train can receive the flash of light at $A'B'$ points simultaneously. Of course, the observer M on the ground surely observes the flash of light at AB points simultaneously. The train and the ground possess the same simultaneous properties, so the time mechanics $t=t'$ is produced. Thus, when train is regarded as mass point, the measurements of space-time of the train's coordinate system and ground coordinate system are identical.

② Light speed is infinite (perceived signal-occurring speed is infinite).

When light speed $c=\infty$, light spends no time in covering any distance, whether the train has length or moves or not, whether at the ground coordinate system (K), or on the train's coordinate system (K'). Flash of light is seen at point M' simultaneously, so is it at point M. The time measurements of coordinate systems K, K' are the same. Obviously, it is equal in value to take train as mass point or to acknowledge light speed is infinite, in measurement mechanics of space-time. So, in fact, Newtonian mechanical mass-point model recognized the existence of signal speed with infinite function. This is the property of Newtonian mechanical timing signal.

Actually, given light speed is infinite, in experience, we can only regard objects as mass point, for infinite light speed enables

all the light given out at different parts to reach observer simultaneously, and the image of the object cannot be distinguished——it is only mass point.

③ The train stays motionless, that is, v=0.

The train is motionless, v=0, and the train and roadbed belong to the same reference system. A', B', M' and A, B, M coincide, and M, M' always receive the flash of light simultaneously, no matter what the light speed is. The space-time measurements are the same in coordinate system K,K'.

It is thus clear that, the train being mass point, timing signal speed infinite and the train motionless, (v=0), all the three are equal in value in the construction of mechanism of space-time, and return to Galileo conversion.

④ Light speed is finite; train has $A'B'$ length and moves in speed v.

Albert Einstein assumed that train had $A'B'$ length and moved in speed v, so came out a central point timing plan; he then deduced the variation of space-time measurement of coordinate system K and K′. If train's speed v is zero, one cannot feel any different information between the things happening on train and on ground. As a result, the difference of space-time of coordinate systems of train and ground depends on the three premises: ① train is not mass point; ② signal speed of perception is not infinite; ③ train's speed must be over zero. It is the above three premises that lead to the differences of space-time measurement in the coordinates of train and ground, which is expressed in Lorentz transformation tangibly or intangibly.

Comparing Newtonian mechanics and special theory of relativity, when reference is abstracted to coordinate system, we find the following three important differences:

First, in Newtonian mechanics, when coordination system is constructed on moving substance (reference), moving object be-

comes mass point, and the changes of simultaneousness caused in motion by the geometric size of substance and observational signal are ignored. While in special theory of relativity, firstly, moving object (reference) is not regarded as mass point, and object (reference) is considered to possess certain geometric size; thereafter, the changes of space-time measurement (conveyer of space-time information) caused by the changes of timing signals on motional object are conversed to the attributes of space-time frame in the coordinate system, through the abstraction from reference to the coordinate system. Secondly, information speed of interaction of perception cannot be infinite. If so, the human beings would not be able to know geometric size of the object, because the signals coming from any parts of the object are received by the observer simultaneously. In infinite action speed, any observed object is only mass point, unless the different parts of the luminous object give out light at different time. In special theory of relativity, electromagnetic field (light) is the signal Albert Einstein used to observe incident, and spreading speed of light is finite. Theoretically, when signal speed conveying incident is not infinite, any objects cannot be regarded as mass point in space-time, because the light from different parts of the object (different events) is impossible to reach the observer simultaneously. And thirdly, in Albert Einstein's special theory of relativity, object is still mass point in discussion of motion laws. How could this be integrated with space-time mechanism formed by finiteness of light speed? Originally, prior to the discussion of motional laws of mass point, special theory of relativity made the abstraction from reference to coordinate system. It transformed the changes of space-time measurement of an object which was not mass point caused by motion into the fixed attribute of coordinate system, in the transformation from reference to coordinate system, and reference was reduced to mass point. Owing to the relativistic attributes of motion, it was specified that any other

motional objects described with this reference also possessed such attributes, and the described object also belonged to mass point. In this way, coordinate system was turned to changeable frame of space-time measurement, and the described object was reduced to mass point; the discussion of the motional laws of mass point constructed special theory of relativity. The space—substance extensiveness was changed from a philosophic concept to a physical one. Special theory of relativity is obviously one step more advanced than Newtonian mechanics in revealing the nature of space-time, which has considered the finiteness of the signal speed in conveying space-time information, and revealed the mechanism of space-time.

It must be pointed out that, owing to the relativistic attribute of motion, when special theory of relativity abstracts mass point, the effects of the "image" of objects on space-time is regarded as the change of space-time attribute of coordinate system, which is similar to recognizing that the "image" of the object moving in this coordinate system is unchangeable and could be ignored, like the neglecting of "image" when Newtonian mechanics abstracts mass point. Therefore, mass point in special theory of relativity still has the attribute of Newtonian mechanical mass point; momentum, energy, location and time are all determined; the motion of mass point also possesses fixed trace.

4.1.2 Attribute of Quantum Mechanical Mass Point & Uncertainty Principle

In microscopic sphere, real micro coordinate cannot be constructed, for we have no way to observe atomic electron's motional trace through experiment. So, Werner Karl Heisenberg said that the track concept of atomic electron was meaningless. To know microscopic object, the human beings could only carry out theoretical construction through experiment, which should include the con-

struction of the "image" of microscopic object. In atomic classical models, what Ernest Rutherford constructed was model of solar system, in which electrons and atomic nucleus were regarded as macro mass point. But this model and the experiments and theory of quantum mechanics are like a round peg in a square hole. Improved Niels Bohr classical quantum theory put forward energy level transition concept of electron motion, in which the electron was still the mass point of classical mechanics and the basic problem of quantum appearance and model was not diminished. Orthodox quantum mechanics attempted to cast aside the more deepened research for structures of atom and electron in dealing with the problems between wave particle duality and experimental appearance but the doubts about the theoretic structure were not cleared up. Could it be said that detailed inquiry about the "image" of electron itself could not be made if we really recognized wave particle duality of microscopic object? Doubtlessly, the more deepened probe of "image" of objects is probing the formation mechanism of the human concept of space-time. If there is "geometric image" of electron, what is the "image" of microscopic object like atomic electron? How can it be constricted? Indeed, the "image" of microscopic object cannot be observed directly, but we cannot regard it as "point" either. "Point" electron of present quantum mechanics is a kind of improper theoretic abstraction.

In macroscopic world, if the size of object can be ignored in our discussion, the object can be simplified to mass point. The motion of object can be regarded as mass point motion. Mass point possesses fixed momentum, location, energy and time; the trajectory of mass point motion is also determined. In microscopic world, can this be done with microscopic particle? Many scientists kept doubting about it, and believed that many problems in quantum mechanics might probably be caused by mass point abstraction. Japanese physicist shoichi Sakata once pointed out: "Originally, it

is tenable regarding elementary particle as mathematical point, which is only taken as research object in bigger space-time sphere, even ignoring the inner structure of elementary particle. While the theoretic form based on point model … usually forgets formerly adopted approximate meaning, so that an illusion has emerged that similarly the research object itself is a mathematical point … elementary particle is a mathematical point …, which is unbelievable. "[2] French mathematician Rene Thom also clearly pointed out: Quantum theory is based on uncertainty, relies on point particle, a rough and unsuitable model, and thrusts microscopic object into the confusion and fallacy caused by an unsuitable concept framework. [3]

Of course, the viewpoints of above scientists are theoretical knowledge. The American physicist Hoffstadt also proved through his experiments that microscopic object was not mass point, with certain distribution radius (as in neutron and proton), for which he won the Nobel Prize in physics. [4] (See Appendix 2) It seems that, real microscopic particle is not mass point, from which consensus can be reached. Then, what problem could arise when microscopic particle is abstracted to mass point (especially in atom)?

In order to answer this question, we first look at the extension of uncertainty principle by L. Landau, Ex-Soviet physicist. In his book *Quantum Electrodynamics*, L. Landau points out that uncertainty principle can be extended to a single physical quantity of Relativistic Mechanics. [5] He believed that in static coordinate system corresponding to particle, uncertain quantity of the coordinate was:

$$\Delta x_0 = \hbar / m_0 c$$

Uncertain quantity of momentum was:

$$\Delta p_0 = m_0 c$$

m_0 is static mass of particle, $m_0 c$ is called "static Compton momentum", $\hbar$(h) is Planck constant. Δx_0 is Compton matter wave wavelength λ_0 divided by 2π, which is equal to the radius with wave-

length λ_0 as circumference, and as we can see that its quantity level happens to be spherical radius $r_0(\Delta x_0)$ of non-point particle (neutron, proton, electron, etc.) measured from experiment.

Just some elaboration and we will find that, the interpretation by L. Landau on Δx_0 can only come from the assumption of point particle of microscopic particle, while in present quantum mechanics, microscopic object like electron is simplified to mass point. Electron is not mass point from origin, with radius $\Delta x_0(=r_0)$; if electron is taken as mass point, then this mass point has to diffuse in the sphere of Δx_0. The size of electron $\Delta x_0(r_0)$ becomes the scope in which electron (mass point) may exist, that is, point electron has certain position distribution error. Thus microscopic object as electron has the position uncertainty. Evidently, the uncertainty of electron and other microscopic objects in position and momentum is given to electron and other microscopic particles consciously or unconsciously when mass point abstraction was made to microscopic object. In physics, λ_0 is often called the characteristic length of microscopic object. It seems that wavelength has connections with the "image" of microscopic object.

To carry out a deep analysis on light—electron colliding experiment made by Werner Karl Heisenberg on uncertainty principle relation, it can also be found that: Heisenberg location uncertainty quantity Δx is the conclusion of motional scope of point particle. Electron is not mass point, and in measurement, once non-mass-point photon meets non-mass-point electron (no matter which part of the electron), the electron is always measured, and one location that it may exist is recorded. However, each measurement cannot determine the exact location of the electron, for its location spreads in its "self-space image". "Electronic self" space image is the only source of location uncertainty caused in single photon—electron colliding experiment.

It appears that, to make mass point abstraction on microscopic

object, the "size" of particle itself cannot be ignored. Theory and experiments change "geometric image" of particle into the new attribute of point particle—uncertainty. Simultaneously, changeability of image has brought about undulatory property of microscopic object. In microscopic world, when "image" cannot be ignored, reality attribute of object is given to "image"; "image" is real, that is, wave is real (space is the reflection of object extension), but mass point is virtual. In quantum mechanics with mass point as its descriptive object, which takes mass point as its descriptive target, "point electron" does have erratic nature in the distribution scope of its "image", so it is very proper to say that electron is "atomic ghost". Human incomprehension or even misunderstanding of probability interpretation is rooted on the ignorance of the new attribute caused by "image-point transition" in microscopic world and the confusion of the different properties of "macroscopic mass point" and "microscopic mass point", especially the oblivion of "image" in "image-point transition".

It can be known from Louis de Broglie stationary wave $\lambda_n = \hbar/p_n$ (p_n as stationary wave momentum, or as track momentum, and also uncertain measurement of momentum, $\Delta p_n = p_n$) on each energy level of hydrogen atom that, when regarding $\Delta x_n = \lambda_n = r_n$ as "reference curvature radius" of atomic electron, it is clear that the "image" of the electron (substance of appearance) Δx_n cannot be ignored in discussing atom issues. According to Werner Karl Heisenberg uncertainty principle equation, in atom:

$$\Delta p_n \cdot \Delta x_n = \hbar \tag{4.1}$$

$$\Delta x_n = \hbar/\Delta p_n = n a_0 \tag{4.2}$$

In the equation, n is principal quantum number, and a_0 is Bohr radius. While atomic energy level radius is:

$$r_n = n^2 a_0 \tag{4.3}$$

In atom, the ratio of the "image" radius of electron to that of atom is:

$$\Delta x_n / r_n = n a_0 / n^2 a_0 = 1/n \tag{4.4}$$

When $n=1$,
$$r_1 = \Delta x_1 = a_0 \tag{4.5}$$

That is, the "image" radius of basic state atom is the same as that of electron. Of course, it is only in the case of basic state, a special case. Even if it is not basic state, the ratio of "electron radius" and "atom radius" is only $1/n$. In atom, the distributing numbers of electrons at each level are at most $2n^2$; If $n=10$, the outmost level of atomic nucleus are 200 electrons, and such element has not been found yet. Even if such element exists, its ratio of "electron radius" and "atom radius" is only 1/10, which obviously does not agree with the condition to ignore "image" in mass point definition in classical mechanics. It indicates that, in discussing atom issues, we cannot ignore the effects of the "image" of electron on the issue.

If electron is really taken as "mass point", the mass point must be within the scope of:

$$x_i \leqslant \Delta x_n$$

With the difference of energy levels in atom, the probability to find "mass point" in Δx_n is also different. "Image" is big, and probability is small; "image" is small, and probability is big, which is what quantum mechanics probability interpretation needs. Curvature interpretation and probability interpretation are interchangeable.

Obviously, Werner Karl Heisenberg is correct when he regarded $\Delta p_n \cdot \Delta x_n \geqslant \hbar$ as the suitable scope of classical mechanical concept, because, when looking at microscopic object outside $\Delta x_n \geqslant \hbar/\Delta p_n$, what is seen is the whole "image" of electron, and the change of "image" fits classical cause-result law, and only then can classical concept be applied; in $\Delta x_n \leqslant \hbar/\Delta p_n$, electron is abstracted to microscopic mass point, which possesses complete different feature from macroscopic mass point—in the scope of Δx_n mass point is uncertain in position and momentum. The curved line (phase circle) encircled by matter wave wavelength possesses both "image" attribute and probability attribute.

Factually, when $n \to \infty$,

$$1/n = 0 \tag{4.6}$$

At this time, electron has left atom and energy may change continuously. What we are discussing now is not the electron's behavior in atom and electron can be considered as mass point in classical mechanics. So, the issue of our discussion returns to classical electrodynamics.

Electron's trace through cloud chamber can also be explained according the comprehension of above physical meaning of uncertainty principle. The location uncertainty measurement Δx of point electron in the track is radius of curvature determined by Louis de Broglie matter wavelength when considering $\Delta p = p$.

The above analysis indicates that, compared with background environment, the bigger the "image" of object is (up to the condition that "image" cannot be ignored), the bigger the uncertain measurement, the stronger the undulatory property ($h \neq 0$). While compared with background condition, the smaller the "image" of object is (the "image" is more likely to be ignored), the weaker the undulatory property is, and the stronger the corpuscular property (or $h \neq 0$). When background environment is infinite, an object of limited image can be separated from background space, and the effect of image can be ignored and abstracted to macroscopic mass point (or $h = 0$), which is the mass point abstract principle in classical mechanics.

To analyze wave particle duality revealed in infinitely deep potential well, barrier potential penetrating and two-slit experiment, the same conclusion can be drawn as the above. [6]

The real source of uncertainty principle is that the image of microscopic object cannot be ignored. The uncertainty of microscopic particle can be revealed in experimental measurement and mass point abstract of microscopic object.

4.2 Description of Macro & Micro Effect Mechanisms & Motional Condition of Object

4.2.1 Macro Effect Mechanism and Motional Condition of Object

In classical mechanics, the interactive forces in our discussion are mainly gravitational force, electromagnetic force, elastic force and friction (mechanical force). Whether the motion of our observed universal celestial body or daily mechanical and electromagnetic motion, we all give a basic premise assumption that interactive mechanism in nature is continuous and uninterrupted. Also in classical mechanics, we believe that gravitational force, electromagnetic force and all mechanical forces in nature are continuous. The establishment of continuous effect (that is, quantum of action $h=0$) inevitably makes the world known by the human beings bear a basic feature to suit it.

The world without interaction does not exist, and the human cognition of the world is inseparable from the understanding of interaction. From their knowledge of gravitational force, the humans summarized the laws of celestial movement; from the cognition of electromagnetic force, they summed up the motional laws of light and electromagnetic field; from mechanical force, the laws of mechanical movement. In classical mechanics, Isaac Newton's first, second and third laws, and universal gravitational law are equations of continuous effect; gravitational field equation of general theory of relativity is equation of continuous effect; so are Coulombian force, Lorentz force equation, James C. Maxwell electromagnetic field equation, and all equations that are described with mechanical effect force. Owing to the continuity of interaction, the motional condition of object is in a process of gradual change rather sudden

change in space-time system.

Classical mechanics is mass point mechanics. Thus, the energy, momentum, location and motional time of object are given to mass point, by which object is replaced. It is also stipulated that space-time points of mass point and coordinate system coincide, and that momentum effect point and space-time point correspond respectively. This should be the physical reason that any two physical measurements (say, momentum and location) are measurable simultaneously, or the physical reason that exchange of momentum and location has a common eigenfunction system.

Owing to the continuity of classical mechanical effect, mass point motion in space-time possesses no "jump" feature, mass point motion is continuous and fixed trajectory motion, and its energy, momentum, location and motional time are determined. Actually, if image and size of object are ignored in classical mechanics, the uncertainty of location, time, momentum and energy can also be obtained in "point" abstraction. Suppose a train is 100 meters long, when it is abstracted to mass point, it indicates that the train's length can be ignored in the discussion (because error is too small). So, such "point" has determined location (generally coinciding with mass center of object), and only such "point" possesses definite motional time and fixed momentum and energy. When train's length cannot be ignored, its length presents measurement error. Thus, naturally, the location of "point" train cannot be determined. The longer the train is, the bigger its uncertainty. The uncertainty of location leads to the uncertainty of length calculation and also speed calculation. Thus, momentum and energy are uncertain. Here, it is assumed that the train is of rigid body, and time measurement has no relation with mass point abstract.

Uncertainty has relation with the length of train Δx , and can be converted to probability of locating "point train" in Δx . When the train is longer, Δx becomes bigger, the chance to locate "point

train" in Δx will be narrower; that is, the probability of locating "point train" will be smaller; when the train is shorter, Δx becomes smaller, the chance to locate "point train" in Δx will be greater; that is, the probability of locating "point train" will be bigger; if the train really becomes point, that is, mass point in classical mechanics, $\Delta x = 0$, the chance to locate the train is 100 %, $\Delta x = 0$ is the condition of classical mass point mechanics. Thus, the uncertainty of energy, momentum, location, and time will disappear.

Of course, if train becomes a sphere, uncertain measurement Δx should be sphere radius. The bigger the radius r, the greater the uncertain measurement $\Delta x (= r)$, the smaller the probability to locate "point sphere" in Δx; the smaller the uncertain measurement Δx, the greater the probability to locate "point sphere" in Δx; $\Delta x = r = 0$, "point sphere" is turned to macroscopic mass point; the probability to locate "point sphere" is 100%. When Δx is connected with sphere curvature, the probability to locate point sphere can also be connected with sphere curvature $\frac{1}{\Delta x}$. When Δx is bigger, bending degree of curvature is smaller and probability is also smaller; if Δx is smaller, bending degree of curvature becomes bigger and probability is greater. Curvature R and probability P are in direct ratio, e. g. $R \propto P$.

Doubtlessly, the image of object is the product of interaction, and changes of the image of macroscopic object are continuous in continuous effect. If it is train, its length is in continuous change; if it is sphere, its radius is also in constant change. When the images of train, sphere and others are looked upon as the "states" given out by interaction, such states are produced from continuous changes. Obviously, the "image" of object seen through the human experience is constructed by the biological instrument of human organs (or plus the extension of scientific instruments). However, it is believed from macroscopic experience that this "image" has un-

changeable properties. It is not space-time function.

In fact, classical Newtonian mechanics is mass point mechanics, in which fixed and unchangeable "image" of object is ignored, the state of object is the motional condition of mass point, and what state equation describes is motional track of mass point, spreading of vibration mode or probability distribution, etc.

This is the basic characteristic of classical mechanics provided by macroscopic effect mechanism.

4.2.2 Microscopic Effect Mechanism and Motional Condition of Object

Microscopic world is different from macroscopic one. In microscopic quantum world, interaction between energy levels is quantized, and discontinuity of interaction is the natural characteristic of interaction in microscopic world.

Let's look at the motion of electron in atom.

What Ernest Rutherford established is atomic model of solar system, which assumes electrons revolve around atomic nucleus as the earth does around the sun (1911). In Rutherford model, electron and atomic nucleus are abstracted to macroscopic mass point and electron and nuclear "sphere", naturally ignored, possess fixed momentum, energy, location and motional time; electromagnetic effect between atomic nucleus and electron is also regarded as continuous effect, namely, electromagnetic effect mechanism in atom has no difference with macroscopic continuous effect mechanism. However, the assumption of Ernest Rutherford could not be compatible with the stability of atom in microscopic world and experimental appearance. As a result, atomic model of solar system had to be given up.

Niels Bohr revised Rutherford solar system model, and put forward energy level transition concept of electron motion (1913). Electron moved around atomic nucleus, its energy change was

quantized. Electron jumped from one energy level to another, absorbing or releasing a photon correspondingly, and photon energy $E=h\nu$ was quantized, which indicated that, electromagnetic function affecting on atomic electron in energy level transition is discontinuous, which is the discontinuous effect from one photon to the next. The motional condition of atomic electron results from sudden change between energy levels. The trajectory motion of macroscopic mass point plus quantized condition is Bohr's semi-classical description of motional condition of atomic electron.

Niels Bohr's semi-classical description of motional condition of atomic electron is also unsatisfactory. On one hand, electron's trajectory is invisible, which is a concept without physical essense, as Werner Karl Heisenberg put it; on the other hand, his semi-classical theory cannot be used to describe wave particle duality of electron, which is still a macroscopic mass point. Quantized condition is an external mechanical supplement.

In 1925, Werner Karl Heisenberg put forward the matrix formulation of quantum mechanics. Later, in 1926, Erwin Schrödinger suggested wave formulation of quantum mechanics. M. Born made probability annotation of wave function, which was revised by Von Neumann and others. This postulate interpretation system of quantum mechanics was generally acknowledged by the majority. Up to this time, quantum mechanics had a complete image from mathematics to physical interpretation. However, atomic electron was still a mass point of no size, whether in Werner Karl Heisenberg matrix formulation of quantum mechanics, or in wave formulation of quantum mechanics, or Copenhagen orthodox interpretation and other interpretations. Electron wave was the probability of point electron appearing at different space-time points, and Erwin Schrödinger equation was evolutional equation of probability. Atomic electron had no motional trajectory, with only the distinction of energy levels. Different energy levels corresponded to the different energy

eigenstates of electron; in different eigenstates, probability of electron was different. Wave function possesses many important properties, among which linear superposition property of state and orthogonal normalization of state is one of the important properties. Our research shows that, the state catastrophe on atomic energy levels is physical cause of orthogonal normalization of wave function. The different normalization methods of non-continuous and continuous numberings of eigenstate reveal the transformation of effect mechanism of non-continuous effect and continuous effects, the change of electron from microscopic "virtual particle" to macroscopic "real particle", the change of matter wave from "real" to "virtual", and the leap from quantitative change to qualitative change.

According to the principle of interaction, space-time is interrelated to the interaction of substances, and then this discontinuous effect is bound to have the process of space and time difficult to define. We once called it space-time "blindness", which is the mutant area of unperceptive image.

The mutation of electron "image" separates electron "states" at different atomic energy levels. Because information is not shown, it indicates that states do not affect each other at energy levels, and in mathematics it shows mutual projection is zero, which is the requirement to construct orthogonal system. Inside atom, owing to the discontinuity of interaction, state numbering is discontinuous. In Hilbert space constructed with state component, electron has probability distribution in each unit vector direction, only that its size is different. The "isolated" states are equivalent to independent interference wave sources, and at energy levels electron transits and gives out photons of fixed frequency, which indicates that, between two energy levels, matter wave has fixed phase difference, and coherence can thus be constructed, which is the property that macro continuous effect does not possess. In macro continuous effect, as object is in space-time sequence, its pre-and

post-states have no discontinuity aroused when information is not shown. Although arrangement of orthogonal normalization can be made to the continuously numbered state function, actually we are unable to change the "component" of continuous "state" at space-time sequence into orthogonal coordinate confirming to the inner condition of atom (independent interference wave sources) with mutational physical meaning in Hilbert space. Mathematical analysis shows that in classical mechanics, while analyzing fundamental wave on a random continuous periodic function, wave is the spreading of motional form of vibrating mass point, and wave phase; continuity of interaction eliminates catastrophe between wavelets. Independent interference wave sources and fixed phase difference disappear and coherence between wavelets does not exist. Making arrangement of orthogonal normalization to continuous numbering state function causes confusion of the two different cognitive levels inside and outside atom, though it will do in mathematics.

Surface wave with δ function normalization has obvious features of mass point mechanics. In $x \neq x_0$ or $p \neq p_0$, $\delta = 0$; in $x = x_0$ or $p = p_0$, $\delta = 1$; in normalization wave function $\delta(x - x_0)$, all component is zero except point $x = x_0$. This is the perfect interpretation of where mass point is and where non-mass point is.[7] δ function normalization (Operate $x = x_0$ or $p = p_0$) , practically similar to a kind of quantum measurement, changes surface wave in quantum mechanics into probability distribution of macroscopic mass point. At this time, wave is virtual, and particle is real. Continuous functioning transforms quantum probability to classical probability. To measure atomic electron wave, correspondence of eigenstate and eigenvalue is to realize this transition, from pure state to mixed state.

In short, in quantum mechanics, discontinuous numbering and continuous numbering of wave function superposition state have their essential differences in physical mechanism. The former cor-

responds to discontinuous effect mechanism, and evolution of state is of catastrophe, between eigenstates there is coherence; the latter corresponds to continuous effect mechanism, and evolution of state is of no catastrophe, wave coherence disappears.

This is the essential difference between the "states" of objects formed by discontinuous effect and continuous effect expressed in space-time sequence.

However, orthodox quantum mechanics has its natural deficiency. On one hand, it still regards microscopic objects such as atomic electron and others as macroscopic mass point, the image of which can be ignored. On the other hand, it mixes the physical realities under two different effect mechanisms. That is the main source of so many paradoxes of orthodox quantum mechanical interpretation. In analyzing experimental appearance of microscopic world, we have found that, in the discussion of atom issues, the image of microscopic object is not ignorable and the energy levels are catastrophic. Quantum mechanics curvature interpretation hits home this vital part. We cannot transcendentally affirm that electron is a bead of unchangeable image. The cognition of the image of such microscopic object itself as electron needs to be constructed through experiments. Quantum mechanics actually constructs the cognition of the "image" of microscopic object at different space-time points through interaction. This "image", or state, is state function of quantum mechanics.

It must be noted that, in atomic world, the "image" of atomic electron we constructed is the product of quantum mechanics, which has essential difference with static "image" "seen" in continuous effect of Newtonian mechanics or relativistic mechanics in macroscopic world. The image of atomic electron is changeable. However, because it is also constructed from optical appearance of electron, we may say, in quantum mechanics, the "image" constructed for electron is the "image" of electron "substance-in-it-

self", namely "substance of appearance"; in space-time, what the human beings can construct is "substance of appearance" but not "substance-in-itself".

Scientific counter-reality theory and the theory of relative reality cast away "substance-in-itself", and only constructed relation through appearance, while we construct "substance of appearance" through interaction.

Quantum mechanics curvature interpretation points out: Inside atomic world, because of the discontinuity of interaction, each component of wave function is an independent interference wave sources; owing to the intervention of continuous effect, electron motion between energy levels changes from catastrophe to continuity; because of the disappearance of independent interference wave sources, coherence declines. Quantum decoherent process, in nature, is to transform discontinuous numbering wave function into continuous numbering wave function through continuous effect and eliminates coherence. In quantum mechanics curvature interpretation, the energy, momentum, location and time of microscopic object are connected with an "image" of limited size; momentum does not function on a certain point, but in a distribution area; the change of momentum Δp corresponds to that of location Δx. So, micro "mass point" has no determined location and trace. In microscopic world, momentum and location "do not commute" (do not possess fixed value simultaneously), or momentum and location do not have common eigenfunction system, which its physical cause ought to lie in.

Obviously, the pattern of human cognition of the objective world is: in macro world, we ignore the "image" of object, and mass point abstracted from "image" possesses the properties of substance and constructs state equation according to the trace of mass point motion, mass point vibration, propagation of vibration mode or probability distribution, while space is virtual. Inside atomic world, we construct electron "image" through optical ap-

pearance, and establish state equation according to the "image" transformation. And "image" is connected with virtual particle probability discovered in the "image", and through "image-point transformation", connection of quantum mechanics curvature interpretation and quantum mechanics probability interpretation is established. Space possesses its substance properties after "light-image transition" and "image-point transition", while "mass point" abstracted from "image" is virtual with uncertainty. In the scope of "image"Δx_n mass point has a property of ghost's. It is obviously wrong that Ernest Rutherford and Niels Bohr regarded atomic electron as macroscopic mass point with the properties of substance. Micro space-time and macro space-time have essential differences, related to the means the human beings used to understand the world and cognitional information object provided to us. Inside atom (discontinuous numbering of eigenstate), the cognition of "state" provided by discontinuous effect is only the law of change of object "image".

4.3 Transformation of Interaction Mechanism in Quantum Measurement

Interaction mechanism in macro classical mechanics has essential differences from that in micro quantum mechanics. Macro mechanism is continuous, whether gravitational force, electromagnetic force or elastic force and friction derived from them; owing to the existence of quantum of action, energy between atomic energy levels is discontinuous, its action is disconnected, as in electromagnetic force, weak interaction force and strong interaction force. Interaction principle indicates, in the known objective world, the "image" of object in space-time sequence is formed through interaction. It is interrelated either with the interaction of objective world itself or the interaction between medium information and human

cognitive organs (including the extension of instrument), and with the properties of observational information the human beings use to observe the world and physiological structure of human brain. The image (state) of object in space-time sequence is connected with interaction mechanism. Continuous action gives out the "image" of continuous change, disconnected action produces disconnected and changeable "image". In quantum mechanics, continuous spectrum plane wave passes δ function normalization and constructs orthogonal system; in such orthogonal system, apart from probability distribution at the point where particle lies, the rest components are all equal to zero. Such superposition state is a "false" superposition state. Although agreeable with Erwin Schrödinger equation, it is, in fact, an wave equation of probability distribution of macroscopic mass point; owing to discontinuous effect, in space-time sequence, "state" components can construct orthogonal system agreeable with internal condition of atom, and superposition state is substantial, globally distributed and with coherence, and its components are simultaneous existent. Differential equation of its state is also Erwin Schrödinger equation.

The above analysis will help us to give reasonable interpretation to difficult problem such as EPR experiments and Schrödinger's cat from the transform of function mechanism.

Let's first look at EPR experiment.

Albert Einstein put forward two judging foundations in EPR experiment:

① Under the condition of no interference on the system, we can definitely predict the value of certain physical quantity, and then this physical quantity corresponds to the essential factor of a physical reality.

② If a theory of physics is perfect, each essential factor of physical reality must have its corresponding object in this theory.

The main factors of physical reality include momentum, loca-

tion, energy, time, etc.

"The interference of the system", as Albert Einstein put it, is "to make quantum measurement". In classical mechanics, without "measurement", we "can definitely predict the value of certain physical quantity" in theory. Therefore, physical quantity in theory has one to one corresponding connection with the main factors of physical reality. Classical mechanics is perfect. But is it correct in quantum mechanics?

In quantum mechanics there is uncertainty principle, which ascertains in microscopic world momentum and location are restricted by uncertainty principle; once momentum is certain, location cannot be completely determined; otherwise, quantum measurement (the interference of the system) has to be made. According to Albert Einstein's judging foundation 1, position is not the corresponding factor of physical reality; on the contrary, once position is determined, momentum cannot be completely determined, so, in like manner, momentum is not the corresponding factor of physical reality. Thus, Albert Einstein reached his conclusion based on his own reality judgment:

If the description of quantum mechanics on reality is mature, each physical quantity of quantum mechanics must correspond to the main factor of physical reality, but uncertainty principle denies this requirement. So, the description of quantum mechanics on reality is not perfect. Through his analysis of reality judging foundation, what Albert Einstein opposed to was still uncertainty principle of quantum mechanics or Copenhagen School interpretation of uncertainty principle. He could not understand the properties of pure state wave function before measurement.

Albert Einstein's criticism of the maturity of quantum mechanics on his own reality judging foundation and the ground of continuous effect confused the difference between microscopic and macroscopic mechanism, which brought doubt to the reasonableness of

his hypothetic experiment.

EPR hypothetic experiment was based on the following consideration: two particles (A and B) formed into compound particle at a certain time through interaction, which then separated and had no interaction any more, thus forming into an interrelated system. Now, if we ask, according to such an ideal experiment designed on EPR demonstration, can "pure state" wave function of orthogonal normalization meeting the requirement of quantum mechanics and separated from each other like atomic inner conditions be produced in interaction?

The answer is: No.

If between A and B is electromagnetic function and also discontinuous electromagnetic effect from one photon to the next, A and B can form orthogonal normalization quantum state; superposition state does exist, but if they are to be separated and have no more interaction, the speed to separate A and B must surpass light speed, which is impossible according to theory of relativity. Albert Einstein denied the tenable possibility of the experiment device in his own theory. If there is no electromagnetic function between A and B, say, collision, mechanical force does not exist after collision, but collision is continuous effect and cannot produce "pure state" wave function of orthogonal normalization meeting the requirement of quantum mechanics and separated from each other like atomic inner conditions. Pre- and post "state" of object produced by continuous effect in space-time sequence does not match catastrophic physical mechanism. Catastrophic superposition state does not exist. Experiment device without catastrophic superposition state is not the experiment device of quantum mechanics needed by EPR demonstration.

Even if electromagnetic function with only one photon is used to realize Albert Einstein's ideal experiment, pure quantum state is bound to be destroyed as the continuous effect intrudes in the process of measurement, and there is no foundation of identical me-

chanical analysis between A and B.

In all, Albert Einstein's ideal experiment device cannot be established at all if the fundamental differences between micro and macro mechanism in the issue of the establishment of object "state".

Therefore, all the analyses of EPR paradox established on the basis of quantum superposition state cannot stand. It is the confusion of macro-state and atomic quantum state that misled people into EPR paradox.

The relative system of compound particle David Bohm imagined is "single-state" composed with two electrons (e_1 and e_2) with total self revolving state as zero. The two electrons fly to opposite directions after separation. Can David Bohm's experiment device avoid the above revealed contradiction and be established? No, obviously. If interaction between the two electrons is quantized electromagnetic function, and if the two electrons then lose electromagnetic function, the speed to separate them is bound to surpass light speed, which is also impossible; if the function between the two electrons is continuous mechanical function, and though they have no more function after separation, the state produced by this function is not pure quantum state, for all analytic foundation of pure quantum state will no more exist. We were confused by multi-particle quantum state, because it is the key point that we did not pay enough attention to the relation between micro mechanism and pure quantum state.

When the difference between the mechanism (the basic difference of discontinuity and continuity) of microscopic world (quantum mechanics) and macroscopic world (classical mechanics) is understood, the paradox caused by "Schrödinger's cat" ideal experiment will perish of itself.

Erwin Schrödinger designed his hypothetic cat experiment like this: a cat and trigger device are place simultaneously in a steel case. Design of the trigger is as follows: a small amount of radioac-

tive atoms is placed in Geiger counter. Within an hour, probability that atoms decay or not decay is equal. If any atoms decay, the counter reflects and acts on an electric relay with a hammer, and the hammer then breaks a small bottle containing hydrocyanic acid so as to kill the cat. If no atom decays within an hour, the cat is still alive. Then, according to Copenhagen interpretation, an hour later, the atoms can be expressed as superposition of decay state and non-decay state and the cat can be expressed as the superposition of dead cat and living cat, that is, in the box, there is an either dead or living cat or a neither dead nor living cat. Because in real world the cat is either dead or alive, a neither dead nor living cat does not exist, then, in Schrödinger's cat experiment, is it that a dead cat or a living cat appears the moment the box is open? Quantum mechanics allows the existence of a neither dead nor living cat before the box is open. Clearly, a dead cat or a living cat is formed instantaneously as the box is open, which is Schrödinger's cat fallacy.

In Schrödinger's cat experiment, atom decay produces photons; owing to light quantum properties, its effect is discontinuous, and because of discontinuous effect, the state before or after atomic decay changes suddenly in space-time succession. The existence of catastrophic pattern constructs orthogonal state. That is to say, the state before decay ψ_1 is the solution of Erwin Schrödinger equation, and the state after decay ψ_2 is also the solution of Erwin Schrödinger equation and owing to linear relation, $\psi_1 + \psi_2$ is again the solution of Erwin Schrödinger equation, and coherence exists, e. g. the reasonable solution that atom either decays or does not decay, which is characteristic of quantum mechanics, and the law of discontinuous effect in microscopic world. However, in Schrödinger's cat ideal experiment, hammer movement, bottle intact or broken, and cat dead or alive, all are not accordance to the applicable condition of quantum mechanics but Newtonian mechanics and their catastrophe is only a concept.

Photon acts on the hammer, which is a mechanical device, the development of whose motional condition accompanies with the interference of mechanical force and gravitational force, and this function is obviously continuous; continuous effects has no concept of energy level transition, state development is continuous but not catastrophic. Therefore, the pre-and post states of hammer in its process ψ_3、ψ_4 do not possess orthogonal property of physical discontinuous effect, nor coherent property of superposition. That is to say, its pre- and post states are not pure quantum state suitable to the inner condition of atom as Erwin Schrödinger equation described. The strike of the bottle by the hammer is also continuous mechanical effect, and the intact state ψ_5 or broken state ψ_6 of the battle has no superposition coherent property, neither has the cat. The process hydrocyanic acid kills the cat is not quantum process at all. The death of the cat is only a gradual process under continuous effect, for between living state or dead state of the cat there is no catastrophe, nor is superposition coherence. Because the condition of quantum mechanical discontinuous effect is damaged, as for the cat, no superposition of a dead or living cat in the box: the cat is either dead, corresponding to atomic decay, or the cat is alive, in the case of no atomic catastrophe; in $\psi_1 + \psi_2$ there is no cat's corresponding state. Whether atom decays or not, and whether the cat dies or not, the whole ideal experiment has undergone an evolution from discontinuous effect (catastrophic, orthogonal and linear) to continuous effect, that is, the transition from suiting quantum mechanical condition to not suiting quantum mechanical condition and then turning to suit macroscopic classical mechanical condition.

Small hammer, bottle and cat are under the control of classical continuous effect conditions, their states can only be changed gradually, so the states, as the described objects of space-time, are determined before or after their evolution. For the cat, there are two independent states: dead or alive, the corresponding state of $\psi_1 + \psi_2$

(superposition coherence) and dead plus living cat does not exist. So, whether you open the box or not, the cat is either dead or alive, depending on whether atom decays and independent of human subjective observation. Of course, if the box is not open we will not know whether the cat is dead or alive, but that is quite another story from Schrödinger's cat paradox. Clearly, Schrödinger's cat paradox ignored the radical difference between the applicable conditions of quantum mechanics and classical mechanics, and was an outlandish confusion of microscopic and macroscopic mechanism. In the whole device, quantum measurement should be the measurement of atom; collapse of wave packet caused after case cover is opened is dislocation of quantum measurement.

According to Von Neumann's hypothesis, even if the cat's fate can be written to pure quantum state, because the effects of "R. Brown performance" fluctuation inside cat's body renders the intervention of continuous effect, the existence of pure quantum state is only of symbolic significance. Once the cat was born, because of its automatic decoherence, it was changed to mixed state in no time, and coherence disappeared, and therefore, the cat in the cage does not present dead and living superposition state. [8]

The analysis of EPR demonstration and Schrödinger's cat will directly help us to understand the nature of instrument interference in quantum measurement. So-called instrument interference is the involvement of continuous effect between microscopic object and instruments. The introduction of continuous effect damages physical orthogonal quantum state of discontinuous effect, the system enters macroscopic mechanism from microscopic mechanism and irreversible measurement process results.

Obviously, when interaction mechanism transits from microscopic discontinuity to macroscopic continuity, our description of "state" of object will convert from the description of the "image" of its space-time to the trajectory of macroscopic mass point in its

space-time or to the probability that mass point appears. The contraction of object's "state" from the "image" of microscopic change to the macroscopic mass point is a transitional process from discontinuous effect to continuous effect, and a process that reflects motional trajectory or classical probability. This is just the physical essence of the transition of Penrose's U process to R process. We may say that, it is identical with the ideas that most of present physicists want to express. Quantum measurement that has confused people for almost a century is going to be clarified. This is our qualitative interpretation of quantum measurement with interaction principle.

Reference

[1] Zhao Guoqiu, Gui Qiquan. New Divine Comedy of Physics [M]. Wuhan Publishing House 2004:174-178.

[2] Shoichi Sakata. Shoichi Sakata Collected Works of Science & Philosophy [M]. Translated by An Du. Beijing: Knowledge Publishing House, 1987:140.

[3] Rene Thom. Mathematical Methods of Morphogenesis [M]. Translated by Zhou Zhongliang. Shanghai: Shanghai Translation Publishing House, 1989:215-280.

[4] R. P. Feynman, C. Miller, et al. Contemporary Physics [M], Beijing: Science Press, 1981:168-173.

[5] Lev D. Landau, et al, Quantum Eectrodynamics, Qxford: Pergmon Press, 1982.

[6] Werner Karl Heisenberg. Die Grundlagen Der Theorie im Reelen und Komplexen [M]. Translated by Wang Zhenghang. Beijing Science Press, 1983:67-88.

[7] Zeng Jinyan. Quantum Mechanics [M]. Beijing Science Press, 1995:676.

[8] Zhao Guoqiu. Re-Consideration of Quantum Decoherence interpretation [J]// China Basic Science, 2006(4).

第四章
宏、微观质点抽象及作用机制的转换

第一节　论经典力学与量子力学中质点的属性

一、经典力学中质点的属性[1]

(一)牛顿力学中质点的属性

唯物主义哲学认为:时间、空间是运动着的物质的存在形式,既没有脱离物质的时空,也没有脱离时空的物质。根据唯物主义关于时空的论述,物理学中人们对物体运动状态的描述,就应包含有对物体自身时空特性的描述。物体的运动状态是由物体间的相互作用决定的,但描述物体运动状态的自然定律,物体在时空中表现的形象特征,都必须通过人类的观察发现。观察需要观测信号和观测仪器。现今人类能利用的场信号有四种:①电磁场(光);②引力场;③弱力场;④强力场。因此,人类认识的物体运动状态及物体在时空中表现的形象特征,必然带有上述四种场的烙印,必然随场的作用性质、作用强弱和作用速度的变化而变化。

按照物理学的理想化方法,如果物体的线度在所研究的问题中不起作用,或所起的作用可忽略不计,我们就可以近似地把物体看作是一个没有形状和大小的理想物体,称作为质点。一般,物体质心所在位置就是质点所在位置。

牛顿的三大定律构成了牛顿力学的基础,而牛顿三大定律又都是以质点为研究对象的,可以说,牛顿力学就是质点力学。质点无大小,谈不上时空形象。人类在观察运动物体,总结运动规律时,凡涉

及到物体自身时空特性的变化全都忽略不计。牛顿力学中，物体在时空中的运动状态，只能由质点的动量、能量及其运动轨迹决定。

从数量上定量确定物体相对参照物的位置或位置随时间的变化，需要在参照物上选用一个固定的坐标系。我们常在参照物上选定一点作为坐标系的原点。通过原点标明长度的线就是坐标轴。

牛顿力学中，物体被简化为质点，因此，当把坐标系建于物体之上时，常常是表明物体的质点就是坐标系的原点。参照物的运动、坐标系的运动、质点(原点)的运动等价。这时物体相对于参照物的运动，也可抽象为质点相对于坐标系的运动。

然而，任何具体物体都绝不会是质点。只要物体不是质点，当我们用某种场信息去观察它时，物体自身的时空特征，必然与物体的运动状态及与观察使用的场信息的性质、强弱和作用的传播速度相关。但在牛顿力学中，人们在建立力学体系时，在从参照物到坐标系的抽象中，根据质点力学的原则，物体自身的几何形象及运动中形象的变化都全部抽掉，任何物体都变成了质点，没有了时空形象。这表明，牛顿力学中完全忽略了运动及观察中使用的场信息对物体时空特征的影响。坐标系是建于物体之上的，抽掉运动及观察信号对参照物时空特性的影响就是抽掉运动及观察信号对坐标系时空特性的影响。因此，牛顿力学中坐标系的运动及观察信号对时空没有影响。客体可以从背景时空中分离出来，与背景时空无关。这也是牛顿力学中“质点”模型对时空绝对性的逻辑要求。可见，牛顿力学中的“质点”远远超出了其最初的意义。

必须特别指出，牛顿力学中，在对物体作质点抽象时，一方面，代表物体的质点在运动中具有确定的动量、能量、位置和时间；另一方面，质点和时空点重合，因此牛顿力学中质点的运动在时空中有确定的运动轨迹。

(二)狭义相对论中质点的属性

狭义相对论中，爱因斯坦是用电磁场(光)作为观察物体时空特性的场信号的，时空体系建立之前参照物不是质点，爱因斯坦“火车对时”实验就是最好的说明。

在“火车对时”实验中，爱因斯坦设“火车”的长度为 $A'B'$，$A'B'$ 的中点 M' 有一个观察者，地面对应的长度为 AB，AB 的中点为 M。

下面分四种情况进行讨论。

①把火车当成质点。

按照质点的定义，质点没有大小，火车上的 A'、B'、M' 重合在一起，不管火车“运动”还是“静止”，显然，两事件之间相互感知的场信号通过火车不需要时间，火车上的观察者 M' 可以同时收到 $A'B'$ 的闪光。当然，地面上的观察者 M 肯定是同时观察到 AB 发来的闪光的。火车和地面具有相同的同时性定义，$t=t'$ 的时空机制即可形成。可见，当把火车看成质点时，火车坐标系(K')与地面坐标系(K)中的时空度量是相同的。

②光速无限大(感知事件发生的信号速度无限大)。

当光速 $c=\infty$ 时，不管火车有无长度，运动与否，也不管是地面坐标系(K)，还是火车坐标系(K')，光通过任何距离都不需要时间。M' 同时看到闪光，M 也同时看到闪光。坐标系 K、K' 的时空量度相同。可见，把火车当成质点与承认光速无限，在时空度量机制上是等价的。所以牛顿力学中的质点模型，实际上承认了有无限大作用信号速度存在。这是牛顿力学对时信号的特点。

其实，当令光速无穷大时，经验上我们只能把物体当成质点，因为无穷大的光速使物体不同部分发出的光全部同时到达观察者，物体的形状无法区分，只能是一个质点。

③火车不动，即 $v=0$。

火车不动，$v=0$，火车与路基属同一参照系。A'、B'、M' 与 A、B、M 永远重合，不管光速如何，M、M' 总是同时收到闪光。坐标系 K、K' 内的时空量度相同。

可见，把火车看成质点，承认对时信号速度无穷大与火车不动($v=0$)，三者在时空机制的建立上都是等价的，都可回到伽利略变换。

④光速有限，火车有长度 $A'B'$，且以速度 v 运动。

爱因斯坦假设火车有长度 $A'B'$，且以速度 v 运动，因而才出现了一个中点对时方案，推导出坐标系 K 与 K' 时空量度的差异。如果火车速度 v 为零，显然没有火车上感知事件发生的信息与地面的不同时。可见，火车坐标系与地面坐标系时空的区别依赖于三个前提：①火车不是质点；②感知事件发生的信号速度不是无穷大；③火

车必须有一个不等于零的速度。是上述三个前提条件造成了火车和地面坐标系中时空量度的差异，并有形或无形地表现在洛仑兹变换中。

牛顿力学与狭义相对论相比，在从参照物到坐标系的抽象中，有如下三点重要区别：

其一，牛顿力学中，在运动物体(参照物)上建立坐标系时，把动体当成了质点，物体因几何大小和观察信号在运动中引起的同时性的变化忽略掉了。而狭义相对论不同，起初它并不把运动物体(参照物)当成质点，而是认为物体(参照物)有一定的几何大小，尔后则把运动物体上因对时信号的变化(时空信息的传递者)引起的时空量度的变化，通过参照物到坐标系的抽象，变成了坐标系中时空框架的属性。其二，感知事件发生的相互作用信息的速度不能是无穷大。如果传递事件发生的信号速度无穷大，那么人类将无法感知物体的几何大小，因为物体任何部位发来的信号都同时到达观察者。在无限大作用速度中，被观察的任何物体都只能是质点，除非发光体不同部位不同时发光。狭义相对论中，爱因斯坦用以观察事件发生的信号是电磁场(光)，光的传播速度是有限的。从理论上讲，当传递事件发生的信号速度不是无穷大时，任何物体在时空中都不能看作是质点，因为物体不同部位发来的光(不同事件)不可能同时到达观察者。其三，爱因斯坦狭义相对论中，讨论物体的运动规律时，物体仍然是质点。这如何与光速度有限形成的时空机制统一呢？原来狭义相对论在讨论质点的运动规律之前，做了一次从参照物到坐标系的抽象，把一个不是质点的物体因运动而引起的时空量度的变化，在参照物到坐标系的转换中，变成了坐标系的固有属性，参照物还原成了质点。由于运动的相对性，于是同时规定凡是以此参照物描述的其他任何运动物体都具有这样的属性，被描述的物体就又可归为质点。这样，坐标系变成时空量度可变的框架，被描述的物体还原成了质点，讨论质点的运动规律，建立起狭义相对论。空间——物质的广延性，由哲学概念转化成为物理概念。狭义相对论在揭示时空产生的本质方面，显然比牛顿力学前进了一步，它考虑到了传递时空信息的信号速度的有限性，揭示了时空产生的机理。

同样必须指出，由于运动的相对性，狭义相对论在做质点抽象

时，物体的“形”对时空的影响被归为坐标系时空特性的变化，它相当于承认在这样的坐标系中运动的物体的“形”不变而且可以忽略不计，类似于牛顿力学中质点抽象时对“形”的忽略。因此狭义相对论中的质点仍然具有牛顿力学质点的属性，动量、能量、位置和时间都是确定的，质点的运动也具有确定的轨迹。

二、量子力学中质点的属性和测不准原理

在微观领域，真正的微观坐标是无法建立的，我们无法通过实验观察原子中电子运动的轨道，所以海森伯说原子中电子的轨道概念是毫无意义的。对微观客体的认识，人类只能通过实验现象进行理论建构，这当然应该包括对微观客体“形”的建构。在原子的经典模型中，卢瑟福建构的是太阳系模型，电子和原子核都可看作是宏观的质点。但这个模型与量子力学实验和理论格格不入。玻尔的经典量子论作了改进，提出电子运动的能级跃迁概念，但电子仍然是经典力学中的质点，量子现象与模型的根本矛盾仍然没有消除。正统量子力学在协调波粒二象性与实验现象之间的矛盾中试图丢掉对原子和电子结构的更深层追究，但是这并没有消除人们对其理论结构的疑虑。难道真的承认了微观客体的波粒二象性，电子本身的“形象”就不能追问了吗？对客体“形”的深究，无疑是在追究人类时空概念的形成机制。如果电子的“几何形象”存在，那么在原子中电子等微观客体的“形”又是什么呢？该如何建构呢？诚然，微观客体的“形”是不能直接观察的，但我们也不能直接把它看成“点”。现行量子力学中的“点”电子是一种不合适的理论抽象。

在宏观世界，如果物体的大小在我们所讨论的问题中可以忽略不计，物体就可以简化为质点。物体的运动就可以看成是质点的运动。质点具有确定的动量、位置、能量和时间，质点运动的轨迹也是确定的。在微观世界，对微观粒子自身还能如此吗？许多科学家一直表示怀疑，而且认为量子力学中的许多问题很可能就是由质点抽象造成的。日本物理学家坂田昌一就指出：“本来，把基本粒子看作数学上的点，只限于在比较大的时空领域作为研究对象，以至于可以忽略基本粒子内部结构的情况下才是成立的。然而，以点模型为基础的理论形式……往往就忘记了当初采取的近似意义，从而产生了

好像所研究的对象本身就是数学上的点这样一种错觉……基本粒子是数学的点……是怎么也不能相信的。”[2]法国数学家托姆也曾明确指出：量子论以不确定性原理为基础，依靠点粒子这一粗糙而不适当的模型，把微观客体硬塞入一种不适当的概念框架所造成的混乱和佯谬之中。[3]

当然，上述科学家的观点是理论上的认识。美国物理学家霍夫斯塔特还从实验上证明了微观客体不是质点，有一定的分布半径（如中子、质子等），并由此获得了诺贝尔物理学奖。[4]（见附录 2）看来，真实的微观粒子不是质点，这是可以达成共识的。那么，当把微观粒子抽象成质点时（尤其在原子中）会带来什么样的问题呢？

为了回答这一问题，我们先来看前苏联物理学家朗道对测不准关系的推广。朗道在他的《量子电动力学》一书中，指出测不准关系可以推广到相对论力学中的单个物理量[5]。他认为，在相对粒子静止的坐标系中，坐标的不确定量是

$$\Delta x_0 = \hbar/m_0 c$$

动量的不确定量是

$$\Delta p_0 = m_0 c$$

m_0 是粒子的静止质量，$m_0 c$ 我们称作为“静止康普顿动量”，$\hbar$(h)是普朗克(Planck)常数。Δx_0 是康普顿物质波波长 λ_0 除以 2π，它等于以波长 λ_0 为圆周的圆的半径。我们将会看到，其数量级刚好就是实验测得的非点粒子（中子、质子、电子等）的球半径 r_0(Δx_0)。

只要稍作推敲就会发现，朗道对 Δx_0 所作的解释，只能来源于微观粒子的点粒子假设，而现行量子力学中，电子等微观客体刚好简化成了质点。电子本来不是质点，具有半径 $\Delta x_0(= r_0)$，如果把电子当成质点，显然，这个质点就必须弥散在 Δx_0 的范围之内。电子的大小 Δx_0(r_0)就成了电子（质点）可能存在的范围，即点电子有一定的位置分布误差。于是，电子等微观客体就有了位置的不确定性。可见，电子等微观客体位置、动量的不确定性，是在对微观客体作质点抽象时，自觉或不自觉地赋予电子等微观粒子的。物理学中常把 λ_0 称作微观客体的特征长度。看来波长与微观客体的“形”是有联系的。

对海森伯证明测不准关系式的光——电子对撞实验作深入分析，同样也可以得出：海森伯的位置不确定量 Δx 是点粒子活动范围

的结论。电子不是质点，测量中只要非质点的光子碰上了非质点的电子，不管碰上电子的哪一部分，电子总是被测到的，并记录一个电子存在的位置。但每一次测量都不能说是电子的准确位置，电子的位置遍布于电子“自身空间形象”之中。“电子自身”的空间形象才是单光子一电子碰撞实验中产生位置不确定性 Δx 的根源。

看来，对微观客体作质点抽象，粒子自身的“大小”不可忽略不计，理论和实验都将粒子的“几何形象”变成了点粒子所具有的新属性——不可确定性。与此同时，形的可变性带来了微观客体的波动性。在微观世界，当“形”不可忽略时，客体的实在属性赋予给了“形”，“形”是实的，也就是波是实的(空间即物质广延的体现)，而质点却是虚的。在以质点为描述对象的量子力学中，“点电子”在其“形”的分布范围内确实有飘忽不定的性质。说电子是“原子幽灵”，其比喻一语中的。人们对概率解释的种种不理解甚至误解，既根源于对微观世界“形点转换”带来新性质的无知，也根源于“宏观质点”与“微观质点”不同性质的混淆，更源于“形点转换”中对“形”的忘却。

其实由氢原子每个能级上德布罗意驻波 $\lambda_n = \hbar/p_n$(p_n 为驻波动量，也为轨道动量，也是电子的动量测不准量，$\Delta p_n = p_n$) 可知，当把 $\Delta x_n = \lambda_n = r_n$ 看成是原子中“电子”的“基准曲率半径”时，电子的“形象”(现象实体) Δx_n 在讨论原子问题时不能忽略是明显的。根据海森伯测不准关系式，原子中：

$$\Delta p_n \cdot \Delta x_n = \hbar \tag{4.1}$$

$$\Delta x_n = \hbar/\Delta p_n = na_0 \tag{4.2}$$

式中 n 是能级量子数，a_0 是玻尔半径。而原子中能级的半径：

$$r_n = n^2 a_0 \tag{4.3}$$

原子中，电子的“形象”半径与原子的“形象”半径之比是

$$\Delta x_n / r_n = na_0 / n^2 a_0 = 1/n \tag{4.4}$$

当 $n = 1$ 时

$$r_1 = \Delta x_1 = a_0 \tag{4.5}$$

即基态原子的“形象”半径与电子的“形象”半径相同。当然，这只是基态，是特例。但即使不是基态，“电子半径”与“原子半径”的比值也只有 $1/n$。原子中每层电子的分布数最多只能是 $2n^2$ 个，若 $n = 10$，则原子核外最外层有 200 个电子，目前还没有发现有这样的元素，即使有这样的元素，“电子半径”与“原子半径”之比也只有 1/10，这与经

典力学中质点定义忽略“形”的条件显然是不符的。它表明，在讨论原子问题时，我们不能忽略电子的“形”对讨论原子问题的影响。

若真要把电子当成“质点”，则质点必须落在

$$x_i \leqslant \Delta x_n$$

的范围之内。原子中随着能级的不同，在 Δx_n 内找到“质点”的概率也不同。“形”大，概率小；“形”小，概率大。这正是量子力学概率解释所需要的。曲率解释与概率解释可以相互转换。

显然，海森伯把 $\Delta p_n \cdot \Delta x_n \geqslant \hbar$ 看作是经典力学概念的适用范围是正确的。因为只有在 $\Delta x_n \geqslant \hbar/\Delta p_n$ 之外看微观客体时，看到的才是电子整体的“形”，而“形”的变化符合经典的因果律，这时经典概念才能适用；在 $\Delta x_n \leqslant \hbar/\Delta p_n$ 之内，电子抽象成了微观的质点，而微观质点具有宏观质点完全不同的性质——在 Δx_n 范围内质点具有位置和动量的不可确定性。由物质波波长围成的曲线（相位圆），既有“形”的属性，也有概率属性。

实际上当 $n \to \infty$ 时

$$1/n = 0 \tag{4.6}$$

这时电子已经离开了原子，能量可连续变化。我们讨论的已不是电子在原子中的行为，电子也就可以当成经典力学中的质点来考虑了。我们讨论的问题回到了经典电动力学。

电子通过云室产生的径迹，亦可用上述对测不准关系物理意义的理解进行解释。径迹中点电子的位置测不准量 Δx，正是当认为 $\Delta p = p$ 时，由德布罗意物质波长决定的曲率半径。

上述分析表明，与背景环境相比，客体的“形”越大，达到“形”不可忽略，测不准量就越大，波动性也就越强（$h \neq 0$）。而与背景环境相比，客体的“形”越小，越接近“形”可以忽略，波动性越弱，粒子性就越强（还可是 $h \neq 0$）。背景环境无穷大，一个有限形体的客体，就可以从背景空间中分离出来，忽略形的影响抽象成宏观质点（可认为 $h=0$），这就是经典力学中的质点抽象原则。

对无限深势阱，势垒穿透和双缝实验中体现出的波粒二象性进行分析，同样可以得到上述相同的结论。[6]

微观客体形的不可忽略，是测不准关系的真正根源。微观粒子的不可确定性，可以在对微观客体做实验测量和作质点抽象时体现

出来。

第二节　宏观、微观作用机制及客体运动状态的描述

一、宏观作用机制及客体的运动状态

在经典力学中，我们讨论的相互作用力主要有引力、电磁力以及弹力和摩擦力(机械力)等。无论是我们观察到的宇宙星体的运动，还是日常生活中的机械运动及电磁运动，我们均赋予了一个基本的前提假设，即相互作用机制本质上是连续的、不间断的。也即在经典力学中，我们认为引力、电磁力及所有的机械力本质上均是连续的作用。连续作用(即认为作用量子 h=0)的设定，必然使人类认识的世界有一个与之相适应的基本特征。

没有相互作用的世界是不存在的，人类对世界的认识离不开对相互作用的认识。对引力的认识，人类总结出了天体运动规律，对电磁力的认识，人类总结出了光和电磁场的运动规律，对机械力的认识，人类总结出了机械运动的规律。在经典力学中，牛顿第一、第二、第三定律、万有引力定律是连续作用的方程，广义相对论的引力场方程亦是连续作用方程；库仑力、洛仑兹力方程是连续作用的方程，麦克斯韦电磁场方程亦是连续作用的方程；一切由机械作用力描述的方程同样也都是连续作用的方程。相互作用的连续性，使得客体的运动状态在时空系列中前后是渐变，而不是突变。

经典力学是质点力学。这样，客体具有的能量、动量、位置和运动时间都赋予给质点了，用质点代替了客体。人们还规定，质点与坐标系中的时空点是重合的，动量的作用点与时空点具有一一对应的关系。这应是任意两个物理量(比如动量和位置)同时可测的物理原因，或者说是动量和位置对易，具有共同本征函数系的物理原因。

经典力学作用的连续性使得质点的运动在时空中不具有“跳跃”特征，质点的运动是连续的、确定的轨道运动，其能量、动量、位置和运动时间都是确定的。其实，如果经典力学中不忽略客体的形状大小，也可以在“点”的抽象中得出位置、时间、动量和能量的不确定性。一列火车，长一百米，当把火车抽象成质点时，是说火车的长度在讨

论的问题中可以忽略不计(因为误差太小)。因此,这样的“点”才有确定的位置(一般与客体的质心重合),也只有这样的“点”才具有确定的运动时间及确定的动量和能量。当火车的长度不可忽略时,火车的长度即为测量误差。这样,“点”火车的位置自然就不可确定了。火车越长,其不可确定度就越大。位置的不确定自然带来了长度计算的不确定,当然也带来了速度计算的不确定。这样,动量和能量也就不确定。这里我们假设火车是刚体,时间计量与质点抽象无关。

不确定性与火车的长度 Δx 有关,并可转换成在 Δx 内找到“点火车”的概率。火车越长,则 Δx 越大,在 Δx 内找到“点火车”的机会就越小,也就是找到“点火车”的概率越小;火车越短,则 Δx 越小,在 Δx 内找到“点火车”的机会就越大,也就是找到“点火车”的概率越大;火车真的变成了点——也就是经典力学中的质点,$\Delta x=0$,找到火车的机会就是100%,$\Delta x=0$ 就是经典质点力学的条件。这样,能量、动量、位置和时间的不确定性也就随之消失。

当然,如果火车变成了一个球体,则不确定量 Δx 就应是球的半径。半径 r 越大,不确定量 $\Delta x(=r)$就越大,在 Δx 内找到“点球体”的概率就越小;Δx 越小,在 Δx 内找到“点球体”的概率就越大;$\Delta x=r=0$,“点球体”变成了宏观质点,找到“点球体”的概率即为100%。当把 Δx 与球面的曲率联系时,找到点球体的概率还可以与球面的曲率 $\frac{1}{\Delta x}$ 联系起来。Δx 越大,曲率越小,概率越小;Δx 越小,曲率越大,概率越大。曲率 R 与概率 P 是成正比例的,即 $R\propto P$。

无疑,客体的形状是相互作用的产物,宏观客体的形状在连续作用中其变化是连续的。若是火车,则火车的长度是连续变化的;若是球体,则球体的半径也是连续变化的。当把火车、球体等形状看作是相互作用给出的“状态”时,则这样的状态正是连续变化生成的。显然,人类经验中看到的客体的“形状”,是由人体器官这架生物仪器(或加科学仪器的延伸)建构起来的。不过在宏观经验中认为这个“形”具有不变的属性。它不是时空的函数。

实际上,经典牛顿力学是质点力学,客体固定不变的“形”忽略掉了,客体的状态就是质点的运动状态,状态方程描述的是质点的运动轨迹、振动形式的传播或概率分布等等。

这就是宏观作用机制给出的经典力学中的基本特征。

二、微观作用机制及客体运动状态

微观世界则不同。在微观量子世界，能级间的相互作用是量子化的，相互作用的不连续性是微观世界相互作用的本质特征。

我们来看电子在原子中的运动。

卢瑟福建立的是原子的太阳系模型，设想电子在原子核周围像地球围绕太阳一样旋转(1911)。在卢瑟福的模型中，电子、原子核都被抽象成宏观质点，电子和核的“球形”被当然地忽略掉了，而且具有确定的动量、能量、位置和运动时间；原子核和电子间的电磁作用也被看作是连续的作用，即原子内部的电磁作用机制与宏观的连续作用机制没有区别。然而，卢瑟福的设想与微观世界原子的稳定性和实验现象不能相容，人们不得不放弃原子的太阳系模型。

玻尔对卢瑟福的太阳系模型作了修正，提出了电子运动的能级跃迁概念(1913)。电子在原子核周围运动，能量变化是量子化的。电子从一个能级跳到另一个能级，对应吸收或放出一个光子，而光子的能量 $E=h\nu$ 是量子化的。这表明，原子中电子在能级跃迁时受到的电磁作用力是不连续的，它是一个光子一个光子的间断作用。原子中电子的运动状态在能级之间是突变的。宏观质点的轨道运动加上量子化条件是玻尔对原子中电子运动状态的半经典描述。

玻尔对原子中电子运动状态的半经典描述不能令人满意。一方面电子的轨道看不见，正如海森伯所说，它是一个没有物理意义的概念；另一方面，玻尔的半经典理论无法描述电子的波粒二象性，电子仍然是一个宏观的质点。量子化条件是一个机械的外在附加物。

1925 年，海森伯提出了量子力学的矩阵表述形式，1926 年薛定谔提出了量子力学的波动表述形式，对波函数玻恩作了概率诠释，经冯·诺依曼等人的修正，量子力学公理化解释体系得到了大多数人的公认。到此，量子力学有了一个从数学到物理诠释的完整形式。不过，不管是海森伯矩阵力学形式，还是薛定谔的波动力学形式；也不管是哥本哈根正统解释，还是其他解释，原子中的电子都仍然是一个没有大小的质点。电子波是点电子在不同时空点上出现的概率，薛定谔方程是概率的演化方程。原子中的电子没有运动轨迹，只有

能级的区分。不同的能级对应电子不同的能量本征态、本征值，不同的本征态，电子出现的概率不同。波函数有许多重要性质，其中态的线性叠加性和态的正交归一性就是重要的性质之一。我们的研究表明，原子中能级之间态的突变性，是波函数正交归一性的物理原因。本征态非连续编号与连续编号归一化方法的不同，体现了非连续作用和连续作用作用机制的转换；体现了电子由微观"虚质点"向宏观"实质点"、物质波由"实"向"虚"的转换。体现了量变到质变的飞跃。

根据相互作用原理，时空与物质间的相互作用相关，那么这种不连续的作用，必然对应有难以定义的空间和时间过程，我们曾把它叫时空"盲区"。时空盲区就是我们无法感知的形态突变区。

电子"形象"的突变，把电子在原子中不同能级上的"状态"隔离了。因为信息不通，表明能级间态与态没有相互影响，数学上表现为相互投影为零。这正是建立正交系的要求。在原子内部，由于相互作用的间断性，态的编号是非连续的。电子在由态的分量构成的希尔伯特空间中，每一基矢方向均有概率分布，只是大小不同而已。被"隔离"的态，相当于独立的相干波源，能级间电子跃迁放出固定频率的光子，预示二能级间物质波有固定周相差，可构成相干性。这是宏观连续作用所不具备的特征。在宏观连续作用中，客体在时空序列中前后状态不具备信息不通的间断性，尽管数学上我们也可以对连续编号的态函数做出正交归一的约定，但实际上，我们无法将在时空序列中连续化的"态"的"分量"变成希尔伯特空间中符合原子内部情态(独立相干波源)的，具有突变物理意义的正交坐标架。数学分析表明，经典力学中一个任意的连续周期函数在基波分析中，波是振动质点运动形式的传播，是相位波，相互作用的连续性使分波之间没有突变性，独立相干波源和固定周相差消失，不存在分波之间的相干性。对连续编号态函数做正交归一性约定，虽然数学上行得通，但无疑带来了原子内部和原子外部两种不同认识层次理解上的混乱。

平面波用 δ 函数归一化，就带有明显的质点力学的特征。$x \neq x_0$ 或 $p \neq p_0$，$\delta = 0$；$x = x_0$ 或 $p = p_0$，$\delta = 1$；归一化波函数 $\delta(x - x_0)$ 中，分量除 $x = x_0$ 点之外，其余均为 0。这正是质点所在处与非质点所在处的绝好说明。[7] δ 函数归一化(令 $x = x_0$ 或 $p = p_0$ 操作)实际上类似一种量子测量，将量子力学中平面波转换成宏观质点的概率

分布来处理。此时，波是虚的，粒子是实的。连续的作用将量子概率转化为经典概率。对原子中的电子波实施测量，本征态与本征值的对应，就是实现这种转换，完成纯态向混合态的转化。

总之，量子力学中，波函数叠加态非连续编号与连续编号在物理机制上有本质的区别。前者对应非连续作用机制，态的演化具有突变性，本征态之间具有相干性；后者对应连续作用机制，态的演化不具有突变性，波的相干性消失。

这是非连续作用与连续作用形成的客体的“状态”在时空序列中表现出的本质差别。

然而，正统量子力学有先天性的不足。一方面，仍然把原子中的电子等微观客体看成形状可以忽略的宏观质点。另一方面，把两种不同作用机制下的物理实在混为一谈，不作区分。这是量子力学正统解释产生诸多悖论的总根源。当对微观世界的实验现象进行分析时，我们发现，讨论原子问题，微观客体的形是不能忽略的，能级间是突变的。量子力学曲率解释正是抓住了这一要害。我们不能先验地认定电子就是一个形象不变的小球。对电子等微观客体自身“形”的认识，需要通过实验现象来建构。量子力学实际上就是通过相互作用在不同时空点上建构对微观客体“形”的认识，这个“形”——状态，就是量子力学中的态函数。

必须注意，在原子世界，我们建构的原子中电子的“形状”是量子力学的产物，它与宏观世界牛顿力学或相对论力学中连续作用“看到”的不变“形状”有本质的区别。原子中电子的形状是可变的。但由于它仍然是电子通过光学现象建构出来的，所以，我们说量子力学中，我们为电子建构的“形”是电子“自在实体”在相空间的“形象”。它是“现象实体”。人类只能建构“现象实体”，而不能建构“自在实体”。

反科学实在论和关系实在论者丢掉了“自在实体”，只通过现象建构关系，而我们却通过相互作用，建构“现象实体”。

量子力学曲率解释指出：原子内部世界，相互作用的非连续性，使得波函数每一个分量都是一个独立的相干波源；连续作用的介入，能级间电子的运动由突变变成了连续，独立相干波源的消失，相干性退出。量子退相干过程，本质上是把非连续编号的波函数通过连续

作用转化成连续编号波函数，消去相干性的过程。量子力学曲率解释中，微观客体具有的能量、动量、位置和时间与一个有限大小的“形”相联系，动量不是作用在一个确定的“点”上，而是作用在一个分布区域，动量的变化 Δp 与位置的变化 Δx 相对应，因此，微观“质点”没有确定的位置和轨迹。在微观世界，动量和位置“不对易”（不能同时具有确定值），或者动量和位置没有共同的本征函数系，其物理原因应该就在于此。

显然，人类对客观世界的认识方式是：在宏观世界，我们忽略了客体的“形”，由“形”抽象出来的质点就具有实体性质，并依质点运动的轨迹、质点振动、振动形式的传播或概率分布建立状态方程，而空间却是虚的；在原子内部世界，我们通过光学现象建构了电子的“形”，并依“形”的变化规律建立状态方程。并且“形”与“形”内找到虚质点的概率相联系，通过“形点转换”，量子力学曲率解释与量子力学概率解释建立了联系。作了“光形转换”和“形点转换”之后空间具有了实体性质，而由“形”抽象出来的“质点”却是虚的，并且具有不确定性。在“形”Δx_n 范围之内质点具有幽灵一样的属性。卢瑟福、玻尔他们把原子中的电子看作具有实体性质的宏观质点，显然是错误的。微观时空与宏观时空有本质的差异，它与人类借以认识世界的手段及客体提供给我们的认识信息相关。在原子内部（本征态的非连续编号），由非连续作用提供的对“态”的认识，只能是客体“形”的变化规律。

第三节　量子测量中相互作用机制的转换

可见，宏观经典力学中的相互作用机制与微观量子力学中的相互作用机制有着本质的差别。宏观作用机制是连续的，不管是引力、电磁力还是由此缘引出的弹力、摩擦力均是如此；由于作用量子的存在，原子中能级间能量是不连续的，其作用是间断的，不管是电磁力、弱力、强力均是如此。相互作用原理指出，人类认识的客观世界，客体在时空序列中的“形象”是通过相互作用形成的。它既与客观世界自身的相互作用相关，也与中介信息同人的认识器官（包括仪器的延伸）的相互作用相关，即与人类观察世界借用的观察信息的性质及人

脑的生理结构相关。客体在时空序列中的形象(状态)本质地与相互作用机制联系在一起。连续的作用,给出连续变化的"形象",间断的作用给出断续变化的"形象"。量子力学中,连续谱平面波通过δ函数归一化并建立正交系,在这样的正交系中除粒子所在点有概率分布外,其余分量均为0。这样的叠加态是一种"虚假"的叠加态。虽然也符合薛定谔方程,其实,它是一个宏观质点的概率分布的波动方程;间断作用在时空序列中"态"的分量可以建构符合原子内部情态的正交系,叠加态是实质性的,全域分布同时存在,而且具有相干性,其状态微分方程也是薛定谔方程。

上述分析将从作用机制的转换上帮助我们对EPR实验、薛定谔猫等疑难作出合理解释。

先看EPR实验。

爱因斯坦在EPR实验中先提出两个判据:

①如果在对系统没有干扰的情况下,我们能够确定地预言一物理量的值,那么这个物理量对应于一个物理实在的要素。

②如果一个物理学理论是完备的,则物理实在的每一要素都必须在这个理论中有它的对应物。

物理实在的要素包括动量、位置、能量、时间等。

爱因斯坦所说的"对系统的干扰"就是"进行量子测量"。经典力学中,不用"测量"我们通过理论就"能够确定地预言一物理量的值"。因此,理论中的物理量与物理实在的要素有一一对应的关系。经典力学是完备的。而在量子力学中还是这样吗?

量子力学中有个测不准关系,它断定在微观世界动量和位置受测不准关系制约,动量确定了,位置就完全不能确定,要确定,就得进行量子测量(对系统进行干扰),按爱因斯坦的判据1,于是位置不是物理实在的对应要素;相反,位置确定了,动量就完全不能确定,相同的道理,于是动量又不是物理实在的对应要素。这样,爱因斯坦根据自己的实在论判据得出结论:

如果量子力学关于实在的描述是完备的,量子力学中的每一物理量就必须都有一个物理实在的要素与之对应,但测不准关系否定了这一要求。因此,量子力学对实在的描述是不完备的。爱因斯坦通过对实在论判据的分析,他反对的,看来仍然是量子力学的测不准

关系或者哥本哈根学派对测不准关系的解释。他不能理解测量前纯态波函数的性质。

爱因斯坦站在连续作用的立场上，用自己的实在论判据对量子力学完备性的批判，混淆了微观作用机制与宏观作用机制的区别，其假想实验的合理性就成了问题了。

EPR 假想实验考虑了如下过程：两个粒子 A 和 B 在某个时刻通过相互作用形成复合粒子，后来彼此分开不再有相互作用，形成了一个复合粒子的相关体系。现在我们要问：根据 EPR 论证所设计的这样一个理想实验，在相互作用中能制备出符合量子力学要求的，像原子内部情态那样彼此分开的正交归一的"纯态"波函数吗？

结论是：不能。

如果 A 和 B 之间是电磁作用，而且是一个光子一个光子的非连续电磁作用，则 A 和 B 可以形成正交归一的量子态，叠加态是存在的，但要想它们分开不再有电磁作用，分开 A、B 的速度就必须超过光速，根据相对论，这是不可能的。爱因斯坦用自己的理论否定了实验装置成立的可能性。如果 A 和 B 之间不是电磁作用，比如碰撞之类，碰撞之后，机械力是不存在，但碰撞是连续作用，它不可能制备出符合量子力学要求的像原子内部情态那样正交归一的量子态。连续作用产生的在时空序列中客体的前后"状态"，不符合突变物理机制。突变的叠加态不存在。没有突变叠加态的实验装置不是 EPR 论证所要的量子力学实验装置。

即使用只有一个光子的电磁作用来实现爱因斯坦的理想实验，但由于测量过程中连续作用的介入，纯量子态必将遭到破坏，A、B 间也已不存在相同的力学分析基础。

总之，如果了解了微观作用机制和宏观作用机制在建立客体"态"的问题上的根本区别，爱因斯坦理想实验装置就根本无法建立。

由此，建立在量子叠加态基础上所做的一切 EPR 悖论的分析工作，当然也就不复存在，是宏观态与原子内部量子态的混淆将人们带进了 EPR 迷雾。

玻姆设想的复合粒子的相关体系是由两个电子 e_1 与 e_2 组成的总自旋为零的"单态"。这两个电子分开后朝相反的方向飞出。玻姆的实验装置能逃脱前面揭示的矛盾而成立吗？显然不能。如果考虑

的两个电子之间的相互作用是量子化的电磁作用，要使两个电子没有电磁作用，分开电子的速度就要大于光速，这当然不可能；如果考虑两个电子之间的作用是连续的机械作用，分开后它们虽然再也没有作用，但这种作用制备的状态不是纯量子态，对纯量子态的一切分析基础不复存在。过去我们之所以在多粒子量子态上纠缠不清，关键是对微观作用机制与纯量子态的关系关注不够。

认识了微观世界（量子力学）与宏观世界（经典力学）作用机制——非连续与连续的根本区别，由“薛定谔猫”理想实验产生的悖论也可以自然消除。

薛定谔是这样设计他的猫论假想实验的：一只猫和扳机同置于钢箱中。扳机设计如下：盖革计数器中置少量放射性物质，在一小时内有原子衰变和没有原子衰变的概率相等。如果有原子衰变，计数器发生反应，并作用于一个装有小锤的继电器，使小锤打碎一个盛有氢氰酸的瓶子，从而毒死箱中的猫。如果一小时内没有原子衰变，猫就还活着。于是，按哥本哈根解释，一小时后，原子可表达成衰变态和未衰变态的叠加，而猫则可表达成死猫和活猫的叠加，即箱中有一只既死又活，或者不死不活的猫。由于真实世界中，猫要么是死了，要么还活着，不死不活的猫不存在，在薛定谔猫实验中，死猫或活猫的出现难道是人打开箱盖观察的瞬间形成的吗？量子力学允许不开箱盖之前有不死不活的猫存在，看来，死猫与活猫只能是开箱看的瞬时形成的。这就是薛定谔猫佯谬。

薛定谔猫的实验中，原子衰变放出光子，由于光的量子特性，其作用是不连续的，非连续作用使在时空系列中演化的原子衰变前后的状态可以突变，突变形态的存在构成了态的正交性。这就是说，衰变前的状态 ψ_1 是薛定谔方程的解，衰变后的状态 ψ_2 也是薛定谔方程的解，由于线性关系，$\psi_1 + \psi_2$ 还是薛定谔方程的解，而且存在相干性，即原子有一个合理的既衰变又不衰变的解。这是量子力学的特征，是微观世界非连续作用的规律。但是，在薛定谔猫理想实验中，小锤的运动，氢氰酸瓶的完好与破碎，猫的死与活，却不符合量子力学适用的条件，而是符合牛顿力学适用的条件。锤的运动、瓶的好与破、猫的死与活，其突变只能是观念上的。

光子作用于小锤，小锤是一个机械装置，其运动状态的演变有机

械力和引力的介入，而这种作用显然是连续的，连续的作用没有能级跃迁概念，状态的演变是连续的，不能突变。因此，小锤在运动过程中的前后状态 ψ_3、ψ_4 不具备物理上的非连续作用的正交性，也不具备叠加相干性质。这就是说，小锤的前后状态不是薛定谔方程描述的符合原子内部情态的纯量子态。氢氰酸瓶子受小锤敲击也是连续的机械作用，瓶的完好状态 ψ_5 与瓶的破碎状态 ψ_6 也无叠加相干性质。猫的死活更是如此，氢氰酸毒死猫的过程绝不是量子过程。猫的死亡只能是一个受连续作用的渐变过程，活猫状态与死猫状态不能突变，也不能叠加相干。由于量子力学非连续性作用的条件被破坏，因此，对于猫来说，箱中不存在活猫和死猫的叠加状态。猫要么死了，它对应原子衰变；要么活着，它对应原子不衰变；$\psi_1+\psi_2$（叠加相干）没有猫的对应状态。从原子的衰变与否到猫的死活，在整个理想实验中，经历了从非连续作用（突变、正交、线性）到连续作用的演化过程，即经历了适合量子力学条件到不适合量子力学条件，转而适合宏观经典力学条件的转化。在整个装置中量子测量应放在原子上，打开箱盖引起波包坍缩是量子测量的错位。

由于小锤、瓶子、猫都处在经典连续作用条件的控制之下，其状态只能渐变，因此，它们的状态在演化前后都是确定的，是宏观时空描述的对象，对于猫来说就只有死与活两种独立的状态，$\psi_1+\psi_2$ 与死猫加活猫的对应状态不存在。这样，不管你打不打开箱子，猫要么死了，要么还活着，它决定于原子是否衰变了，与人的主观观察无关。当然，人不去打开箱子，我们是不知道猫的死活的，但这与薛定谔猫悖论是两回事。看来，薛定谔猫悖论的产生，原因是忽视了量子力学和经典力学适用条件的根本差别，它是微观作用机制与宏观作用机制混淆形成的怪胎。

即使按冯・诺依曼假设，猫的死活可以写成纯量子态，但由于猫自身内部“布朗运动式”涨落的影响，使得连续作用的介入，纯量子态的存在也只有象征意义。猫一旦出生，由于自动退相干，几乎不要时间就变成了混合态，相干即可消失，笼中的猫不可能有死活的叠加态。[8]

对 EPR 论证和薛定谔猫的分析将直接帮助我们理解量子测量中仪器干扰问题的本质。所谓仪器的干扰，就是微观客体与仪器之

间连续作用的介入。连续作用的介入，破坏了非连续作用物理上的正交量子态，系统从微观作用机制进入宏观作用机制，不可逆的测量过程也就产生了。

很明显，当相互作用机制由微观不连续向宏观连续过渡时，我们对客体“状态”的描述，也由对其时空中“形”的描述，转而对其时空中宏观质点轨迹或质点出现的概率的描述。客体的“状态”由微观变化的“形”向宏观质点收缩，并表现出运动轨迹或经典概率的过程，是一个由非连续作用向连续作用过渡的过程。这正是 Penrose 的 U 过程向 R 过程过渡的物理实质。应该说，这与当今大多数物理学家要表达的思想是一致的。困惑了人们近百年的量子测量，看来也有了澄清之日。这就是我们运用相互作用原理对量子测量的定性解读。

参考文献

[1] 赵国求，桂起权. 物理学的新神曲[M]. 武汉：武汉出版社，2004：174-178.
[2] 坂田昌一. 坂田昌一科学哲学论文集[M]. 安度，译. 知识出版社 1987：140.
[3] 雷内・托姆. 突变论：思想和应用[M]. 周仲良，译. 上海：上海译文出版社，1989：215-280.
[4] 费因曼，C. 米勒. 今天的物理学[M]. 叶悦，等译. 北京：科学出版社，1981：168-173.
[5] Lev D. Landau，et al Quantum Eectrodynamics，Qxford：Pergmon Press，1982.
[6] 海森伯. 量子论的物理学原理[M]. 王正行，译. 北京：科学出版社，1983：67-88.
[7] 曾谨言. 量子力学[M]. 北京：科学出版社，1995：676.
[8] 赵国求. 量子退相干解释的再思考[J]//中国基础科学，2006(4).

Chapter 5
Classical Probability, Quantum Probability & Visibility Interpretation of Probability

Confidence (subjective) interpretation, confirmation (logic) interpretation, and frequency (validity) interpretation are all called the classical interpretation of probability; while the variation of probability concept brought about in application of quantum mechanics is called quantum probability. Quantum probability and classical probability either have connection or difference in concept. By means of probability "visibility interpretation", to apply probability definition reasonably to a single incident and wave interference, quantum mechanics probability interpretation and quantum mechanical curvature interpretation can be interrelated so as to eliminate the tangling of empiricism and reasonably explain two-slit interference experiment of electron.

5.1 Classical Probability

5.1.1 Several Interpretation of Probability

5.1.1.1 Confidence interpretation[1]

Confidence interpretation of probability is also called belief interpretation or subjective interpretation. Its representatives are Ramsay, De Finnerty and Savici (Savici called it personal interpretation). So-called confidence indicates the confidence degree of a

given individual towards the truth of a given subject. That is to say, probability is the measurement of the rationality of personal belief. Probability confidence interpretation indicates, the incident itself has no probability, and the reason that probability is designated to an incident is only the evidence of belief in the probability designator's mind. On one hand, different people have different degree of belief of the same incident, so confidence is relative; on the other hand, confidence varies with the development of personal cognition and possessed knowledge, so confidence is changeable. Variation and relativity of confidence is the core of probability subjective interpretation.

Many examples can be sited to deepen the comprehension of probability subjective interpretation. Gambling is a case in point. When someone makes a bet, where his bet is put, how many, win or lose, all these are the belief of the gambler, not involving any objective statistic data. The probability of winning and losing is subjective evaluation, personal confidence of the probable incident, which is also the important reason why this probability is called subjective probability. Subjective probability requires that each person of reasonable belief shall keep the same confidence during the whole period, avoiding self-contradiction. Though it is intentional as the measurement of belief rationality, this subjective probability still abides by probability calculation axiom and agrees with the cause-effect relation.

5.1.1.2 Logic interpretation (confirmation interpretation)

The interpretation of probability, besides subjective interpretation, also includes logic interpretation, the representative of which is Rudolf Carnap. Logic interpretation is defined through the measurement of confirmation (solid evidence) of probable incident. Confirmation is a kind of logic reasoning of probable incident, say, to regard inductive logic as logical relation of random subject H (hypothesis) and evidence E, that is, inductive support of E to H.

Thus, in principle, probability value $P(H,E)$ (read the probability of H to E) can at least be defined single-valued. Take weather forecast as an example. Before weather forecast, meteorological data is to be collected, and then analyzed, and through logic reasoning, tomorrow's weather is deduced as "fine" or "rain", the probability of stochastic event. Here, the collected data (meteorological data) is not necessarily related directly with predicted stochastic event, "fine or rain", but there is relation in logic, thus regarded as the supporting evidence of probable incident in certain degree. For example, through logic analysis of meteorological data, the probability of rain tomorrow is 80%. But note that, the 80% of probability to rain is only the result of logic reasoning. First, it is not fact because tomorrow has not come. Second, it cannot be understood as a relative frequency of factual occurrence. And the last, it does not mean that the forecast is determined. 80% of probability is not equal to the fact at all, whether it rains or not, it is only a confirmation, nothing more. It seems, in its logic interpretation, probability is neither factual nor authenticable. Narration of probability has not any direct inevitable connection with result of experience. [2] It is a kind of prediction of concerned invent through the logic relation of informational data. The probability itself of the concerned invent is of perception while the happening of concerned invent is limited by cause-effect relation.

5.1.1.3 Frequency interpretation

Probability frequency interpretation, also named objective interpretation (validity interpretation), indicates the relative frequency of a happening H in a given event E. the precise definition is: the value P of designated probability is a limit value of relative frequency expressed in a long tendency by an infinite succession E of repeating event H. its mathematical equation is:

$$P(H,E) = \lim_{n \to \infty} m/n \tag{5.1}$$

In which: $0 \leqslant m \leqslant n$, $0 \leqslant P \leqslant 1$, m is frequency of H, n is the to-

tal frequency of E, and m, n are integer. In frequency interpretation, probability is the maximum of integer and integer ratio. Note: "category" of events is the condition that probability is formed. The difference of selected "category" decides the difference of probability value.[3] probability frequency interpretation has no need to assume "stochastic event non-difference principle", but calculates the probability of stochastic event through relative frequency limit according to the objective condition of the event, which then is also called objective probability. Probability frequency interpretation has its defects, that is, when relative frequency limit does not exist, probability cannot be defined. Meanwhile, frequency interpretation does not apply to single event or hypothesis.

The relation between relative frequency and probability in probability frequency interpretation is illustrated as follows:

Cast a coin, when $n \to \infty$, and the probability of obverse side up is 50%, but when n is not infinite, the relative frequency of obverse side up is changeable. Chart 5-1 illustrates the experimental data of the three persons A, B and C casting coins. According relative frequency calculation equation:

$$f_i = m/n \tag{5.2}$$

relative frequency can be calculated. See chart 5-1:

Chart 5-1 Relative frequency experimental data

persons	number of experiment (n)	time of obverse side up (m)	relative frequency (f_i)
A	4040	2048	0.5469
B	12000	6019	0.5016
C	24000	12012	0.5005

From chart 5-1 we can see that, numeral value of relative frequency does not equal exact 0.5, but with the increase of the number of the experiment, relative frequency gradually draw near limit

value 0. 5. This 0. 5 is the probability of obverse side up when $n \to \infty$.

Probability frequency interpretation has its defects but also advantages. Its advantage lies in: the emphasis of the objectiveness of probability, the connection of probability with scientific experiment, and the ascertainment of the existence of statistic law in objective world. However, we must notice, objective probability is only the law of statistics of great number, a kind of knowledge, not to be used in the definition of single event. Single event cannot be defined with probability but relative frequency. While probability "visibility interpretation" contains the connotation of the above two and we may make the most of the advantages and avoid defects, which will be elaborated in part four.

5.1.2 Characteristics of Classical Probability

5.1.2.1 Knowledge attribute of probability and causality of single stochastic event

Subjective interpretation, logic interpretation and frequency interpretation of probability are collectively called classical probability. One of the important features of classical probability is the knowledge attribute of probability and causality of single stochastic event. Probability expresses a kind of mathematical knowledge and represents the law of statistics of the occurrence of a kind of event; the occurrence of a single event is controlled by classical mechanics. In the subjective interpretation of probability, for example, when a gambler makes a bet, what he depends on is totally his subjective judgment. Of course, he may have his own foundation, say, he judges by "non-difference principle" and "shaking gesture of banker's hand", etc. This is the process of the formation of confidence. However, the degree of his confidence has nothing to do with dice points. Therefore, the probability of gambler's estimation is the degree of his belief, subjective but not objective. Only when the banker lifts the cover can subjective probability be transformed

to objective reality. This transformation is not restricted by subjective but objective conditions. The occurrence of stochastic event matches the cause-effect relations of classical mechanics. Of course, subjectivity may agree with objectivity or may not. The probability of agreement is 1, and disagreement is 0. Generally, subjective probability is a percentage somewhere between (0,1), while in reality there is only "yes(1)" or "no (0)". We call this catastrophe of subjective probability to objective reality (0, 1). Probability logic interpretation also has such similar cases. In weather forecast, meteorological data and the result of forecast is the relation of logic reasoning. It is only a prediction to say there is 60% of probability to rain tomorrow, the conclusion of comprehensive analysis of various meteorological data. It is the process of the formation of probability, which has no inevitable inner connection with the fact that it rains tomorrow. However, when it is really tomorrow, whether "fine" or "rain", the probability of "rain" is 0 in "fine" day, and the probability of "rain" is 1 in "rainy day". In real tomorrow, the probability of rain still changes between (0, 1). Weather forecast "tomorrow it rains 60% probably" is still a kind of relative knowledge of the weather, illustrating the process to change from subjectivity to objectivity, and this change is restricted by weather factors independent of human subjective judgment.

Probability frequency interpretation has no exception. Although the probability from frequency interpretation is called objective probability, it only refers to the formation of probability. Objective probability is the regular measurement of great number, and probability itself is still a kind of mathematic knowledge. In equation (5. 1), $n \to \infty$ indicates the probability of occurrence of stochastic event accompanied with great number counting process, the process from concreteness to abstractness. Thus, the process to get the probability is in fact the process of advance from single physical reality to concept or knowledge. In casting coins, the 50%

probability of obverse side and reverse side respectively also indicates the law of great number calculation. Usually we pay more attention to the process of reaching the probability and ignore its reverse process. So-called reverse process is that, after we know the probability of the occurrence of certain stochastic event through great number counting, we observe the process of occurrence of stochastic event again. For example, in casting coins, although we already know the 50% probability of obverse side and reverse side respectively, while in each casting afterwards, there are only two definite conditions: either obverse side up or reverse side up. To express it with probability, the probability of obverse side up (or reverse side up) is either 1 or 0. And the occurrence of single event is controlled by the condition of classical mechanics. From it we may conclude: if the process of analysis and deduction of great number counting is regarded as the process of advance from single physical reality (0, 1) to conceptual knowledge, then reversely, re-observe the process of single stochastic event can also be regarded as the reverse process from concept (knowledge) to physical reality (0, 1). No matter which interpretation of probability, no matter how difficult the original condition and how unpredictable, when single stochastic event occurs, its physical mechanism is bound to be restricted by the cause-effect-relation of classical mechanics.

5.1.2.2 Superposition of probability

Let's examine the description of classical probability on bullet (electron is replace by bullet) passing through two-slit experiment. [4] As is shown in chart 5.1: A is bullet emitter. First step, close slit S_2 and open S_1, obtain probability distribution curvature P_1 of bullet on screen B. Second step, close S_1, only open S_2, obtain probability distribution curvature P_2 of bullet on screen B. The third step, open S_1 and S_2 simultaneously, obtain distribution curvature P, and

$$P=P_1+P_2 \tag{5.3}$$

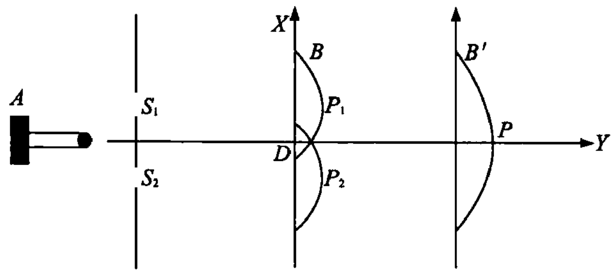


Chart 5.1 description of classical probability on bullet passing through two-slit experiment

It indicates classical probability agrees with superposition principle.

5.1.2.3 Conditional property of probability

In probability subjective interpretation, when a person forms his subjective probability, his most basic foundation is his belief on the "non-difference principle" in stochastic event. As for coin or dice, this "non-difference principle" is their "equality of material quality", which in fact is the condition of subjective probability. If the material quality of coin and dice is "not equal" and someone knows this "inequality", the subjective probability he forms is certainly different from the others who do not know it. In logic interpretation of probability, the probability of occurrence of a certain subject (event) is deduced through the logic relation of the event with other subjects (events). As is in the case of the above weather forecast, weatherman's meteorological data determines the degree of accurácy of the weather forecast. The more meteorological data he has, the more comprehensive, the higher the accuracy degree of the weather forecast, and his mastery of the meteorological data, of course, becomes the condition of formation of logic probability. In probability frequency interpretation, the difference of "category" chosen for comparison of stochastic event determines the difference of probability. For example, the probability of cancer patients who

smoke in the ratio of the city dwellers is different from the probability of cancer patients who smoke in the ratio of smokers. In the same stochastic event, the "categories" chosen for comparison (the city dwellers and smokers) are different, so their probability is different. Here, the choice of "category" is the condition to produce probability.

Generally, if R is stronger condition than S_i, that is, the event that satisfies R also satisfies S_i, In N times stochastic experiments under condition S_i, event R occurs N_R times, and the probability (chances) of the occurrence of event R under condition S_i R is:[3]

$$P(R/S_i) = \lim_{n\to\infty} N_R/N \tag{5.4}$$

The event that satisfies both condition A and condition R is called "$R \cdot A$" event. If in N times stochastic experiments under condition S_i, event $R \cdot A$ occurs $N_{R\cdot A}$ times, and the probability (chances) of the occurrence of event $R \cdot A$ under condition $S_i R$ is:

$$P(R \cdot A/S_i) = \lim_{n\to\infty} N_{R\cdot A}/N \tag{5.5}$$

And in the experiments that event R occurs N_R times, event A occurs $N_{R\cdot A}$ times, and therefore, under condition R, the probability (chances) of occurrence of event A is:

$$P(A/R) = \lim_{n\to\infty} N_{R\cdot A}/N_R \tag{5.6}$$

Equation (5.5) divides equation (5.4), we have:

$$P(R \cdot A/S_i)/P(R/S_i) = \lim_{n\to\infty} N_{R\cdot A}/N_R \tag{5.7}$$

Compare equation (5.7) and equation (5.6), we have:

$$P(A/R) = P(R \cdot A/S_i)/P(R/S_i) \tag{5.8}$$

In equation (5.8), only when condition $R = S_i$, can we have:

$$P(A/R) = P(R \cdot A/S_i) \tag{5.9}$$

Or:

$$P(A/R) \neq P(R \cdot A/S_i) \tag{5.10}$$

Equation (5.10) indicates that the probability (chances) of occurrence of the same event will change with the variation of the classical statistical conditions, but the change is not what is mentioned

from concept to physical reality (0, 1). Conversion from concept to physical reality is restricted by cause-effect relation, the restriction of deeper level mechanics bordering condition behind it, which is very important to know in the cognition of quantum probability.

5.2 Quantum Probability

Not long after Werner Karl Heisenberg put forward quantum mechanics matrix form (1925), Erwin Schrödinger put forward wave form of quantum mechanics (1926). In Erwin Schrödinger's wave equation, wave function ψ described electron motional state. The one who first gave explicit meaning to wave function ψ is M. Born, who pointed out in 1926 in a paper entitled " On Quantum Mechanics in Collision Process": $|\psi|^2 d\tau$ measures the probability to find particles in space volume element $d\tau$. This is Born probability interpretation of wave function ψ. According to M. Born comprehension at that time, microscopic particles as electrons was imagined as mass point of classical significance which possessed fixed location and definite momentum at any moment. [5] Wave mechanics does not answer the question "what is the accurate state of particle after collision?", but only answers "what probability of certain fixed state after collision?". In quantum mechanics, what can be said about all events is only in what probability a certain event occurs, and this probability depends on wave function ψ square of probability wave (at first, M. Born did not emphasize "square", and made revision later). Electron wave is the wave that changes with probability. Born probability wave overcame some difficulties of physical reality wave put forward by Erwin Schrödinger and others, such as wave packet diffusion, etc. M. Born succeeded. But Born probability interpretation of primitive classical significance (not distinguishing the difference between "probability" and "probability amplitude") met its depressed failure when it was used to

explain the phenomena as electron single-slit diffraction and two-slit interference. Electron wave probability is not the probability of classical significance, for the probability wave corresponding to electron does abide by classical probability superposition principle mentioned before, that is, classical cause-effect law. Quantum probability possesses wave interference effects. Chart 5. 2 explains this interference effect.

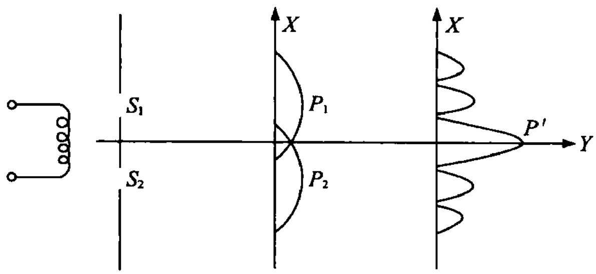


Chart 5.2 Electron two-slit interference experiment

In chart 5. 2, after electron passes two-slit S_1, S_2, it does not form superposition curvature P as shown in chart 5. 1 but interference pattern P'. The experiment is made when electron flow is extremely weak so that only one particle passes the instrument each time. From mathematical analysis, it is known that the wave each electron brings interferes with itself. "Mathematical wave" interference can be shown on screen through physical distribution of particles, which means electron wave contains a kind of real physical function. Therefore, wave function certainly possesses certain physical reality, and quantum probability should not be something of knowledge under classical probability significance, say, not knowledge wave of classical significance (mathematical wave), which is an important difference between quantum probability and classical probability.

According to M. Born comprehension of quantum probability classical pattern, $|\psi|^2 d\tau$ should be the probability of occurrence of

particle in volume element $d\tau$. According to the interpretation implication of probability frequency, $|\psi|^2 d\tau$ should be expressed as the ratio of certain integer and another, that is, the ratio of times (integer) electron appears in volume element $d\tau$ and times (integer) electron appears in volume τ. However, any one concrete wave function cannot reveal integer ratio of probability, which is another great obstacle in understanding wave function as probability. Electron two-slit experiment indicates, quantum probability does not possess superposition property of classical probability, and that quantum probability, different from classical probability, does not follow the law of classical mechanics. Quantum probability possesses coherence. When "God plays dice", either state ① or state ② may appear, and even states ①+② may exist simultaneously with coherent attribute. Mathematical analysis also indicates, electron wave interferes with itself, and an electron can pass through two slits, which is not understandable in classical mechanics. Quantum probability should have different mechanical foundations. Yet electron placement on screen possesses the character of classical probability. An electron, falling on location A, will not fall on location B of the screen (shown by brightened dot), the placement of each element (electron) constructing quantum probability still possesses the determining attribute of (0, 1), (1,0).

How can we solve the problem that quantum probability either has different essence from classical probability or classical probability (0,1) character in the transition from probability to physical reality? It is really a test of human intelligence. Physicists and philosophers have two ways of thinking: the first, electron wave is not mathematical wave (probability wave) but physical wave. Louis de Broglie, Erwin Schrödinger, Madelung and others were its representatives, and Albert Einstein was its active supporter. The second, electron wave is probability wave, because placement of electrons on screen is statistical. However, wave function cannot

be completely regarded as a mathematical fabrication, but a potential physical reality. Interference of pure mathematical wave cannot produce real physical function. It is believed that only real physical interaction can produce real physical effects——interference patterns. Copenhagen School was its representative. Werner Karl Heisenberg believed a "potential" and "tendency" controls the occurrence of quantum probability. It is the reality at the middle level between substance and spirit. Probability wave in quantum mechanics was regarded as probability wave controlled by "potential" or "tendency", which means the deeper foundation determined quantum probability is not classical Newtonian mechanics and relativistic mechanics but "potential" or "tendency" at the middle level between "substance reality" and "conceptual spirit", regarded as a new-type "physical reality". What is the mechanical foundation of "potential" and "tendency"? Not clear. However, when attempting to make probability interpretation of electron's path through Wilson cloud chamber, Werner Karl Heisenberg gave microscopic particles the uncertainty property of momentum and location. It was this uncertainty property that individualized "potential" and "tendency" in electron two-slit experiment. So, Werner Karl Heisenberg said: "This uncertainty is the basic cause that statistical relation occurs in quantum mechanics." Thus, the appearance of quantum probability does not need such unknown mechanical border condition as classical probability; the occurrence of its statistical property is completed by uncertainty of microscopic particle itself. [5]

The reason for the formation of classical probability is uncontrollability of mechanical initial condition of happening, but the occurrence of event still follows the basic laws of Newtonian mechanics and relativistic mechanics; and the reason for quantum probability to be established is the uncertainty of momentum and location essentially possessed by microscopic particle itself. This "uncertainty" of microscopic world is characteristic of particle itself, inde-

pendent of external foundation. On the contrary, it is this "uncertainty" that has established "new" mechanical foundation of substance movement. That is the essence of orthodox interpretation of so-called "quantum mechanics". Is "uncertainty" really the character of particle itself? In microscopic world, do all microscopic particles really "suffer from minimal brain dysfunction"? In nearly a century, a whole string of paradoxes have appeared around the orthodox interpretation of quantum mechanics. For example, the argument is still going on whether wave function of quantum mechanics is physical wave or mathematical wave. On my knowledge from the research, there are at least the following issues worth discussion.

First, Erwin Schrödinger equation is established on the basis of classical electromagnetism. Therefore, Erwin Schrödinger equation is of determinism, which was called U process by Roger Penrose. The questions are: Electron cannot be determined by a location and momentum, but evolution of its motional equation is determined? The equation that describes the action of electron motion does not need electron to possess determined momentum and location simultaneously? Electron has no determined location and momentum, but has determined state?

Second, "uncertainty" of Werner Karl Heisenberg only provided a purposefully established theoretic foundation for the statistics of electron's brightened dots on screen or wave function probability, which is of axiom character. Uncertainty has not solved the problem of electron wave interference. Physical mechanism of wave interference which electron shows through two-slit is neither clear nor definite. So, another question arouses whether statistics of electron's brightened dots is accomplished in the moment of measurement. Roger Penrose called it R process. Niels Bohr believed electron's wave and corpuscular properties were given to electron by the designed instrument system; to design electron in wave instrument system, it would show wave property, and to design elec-

tron in particle instrument system, it would show corpuscular property. Electron wave particle duality belongs to appearance state, regarded as the product of the human experience. Electron wave is purely empirical.

Third, electron should follow classical mechanics in the interpretation of Erwin Schrödinger equation. While the interpretation of electron through two-slit interference effect indicated electron did not comply with classical mechanics, and uncertainty property needed to be given to electron itself. So, to explain microscopic physical phenomena, an electron was shoved around between determinism and non-determinism, and the human cognition became ever confused. The human beings are at their wits end about this tiny electron? No.

Quantum mechanics curvature interpretation is a good method in our attempt to solve this problem.

5.3 Visibility Interpretation of Probability (Discussion)

Curvature R expresses bending degree of curved surface; the bigger curvature is, the more distinct corpuscular property is, and the smaller curvature is, the more obscure corpuscular property is. Therefore, the size of curvature R can express "observable degree" of electron corpuscular property. $\Delta p \neq 0, \infty; \Delta x \neq \infty, 0; R \neq 0$, space is curved with "visibility", and corpuscular property appears. When R becomes bigger, curvature is bigger, visibility is broader, and corpuscular property is stronger. $R = \infty (\Delta p = \infty, \Delta x = 0)$, electron changes to mass point, with accurate position, and visibility is 100%; $R = 0 (\Delta p = 0, \Delta x = \infty)$, curvature is 0, corpuscular property disappears and is invisible, and "visibility" is 0.

Curvature R, also corresponds well to "probability" through "visible degree" (a new term for this book). Probability variation can be "translated" into curvature variation. As for probability in-

terpretation, in uncertainty principle, if Δp is bigger, Δx is smaller, and the probability for electron to appear is bigger; if Δp is smaller, Δx is bigger, and the probability for electron to appear is smaller. The probability for electron to appear can be regarded as "visible degree" of electron. Big probability indicates that "visible degree" here is big, and small probability shows that "visible degree" here is small. The relation between probability ρ, Δx and visibility is:

$$\rho \propto \frac{1}{\Delta x} \propto \text{Visibility}$$

As for curvature interpretation, in uncertainty principle, if Δp is bigger, Δx is smaller, curvature R is bigger, corpuscular property is stronger, and visibility is bigger; if Δp is smaller, Δx is bigger, curvature R is smaller, corpuscular property is weaker and visibility is smaller. The relation between curvature R, Δx and visibility is:

$$R \propto \frac{1}{\Delta x} \propto \text{Visibility}$$

So,

$$\rho \propto R \propto \text{Visibility}$$

The three of ρ, R and visibility form organic internal connection through Δx (or matter wave wavelength λ) in uncertainty principle.

In order to solve the problems in quantum mechanics interpretation, it is necessary and possible for us to extend the connotation of probability interpretation.

In microscopic world, our object of research is not point particle, but object with certain geometric image. However, we can change geometrical property of particle into uncertain property of point particle through point particle abstract. Or put it in an opposite way, we can return the uncertainty of point particle to the geometrical property of particle. If particle geometrical property is characterized with curvature, quantum mechanics probability interpretation will automatically turn to quantum mechanics curvature

interpretation.[6] Particle geometrical image is visible; When bending degree of particle surface is regarded as a measurement of visibility, uncertainty property microscopic particle essentially posseses is cast away, and theoretically it returns to the theory of substance-in-itself, which establishes the theory of mass point abstract.

In experiment survey, light dots random appear on the screen. Where more light dots spread, visibility (distinction of vision) is broader; where less light dots spread, visibility is narrower; where there is no light dot, visibility is zero, invisible. The visibility here is the law of great number counting; the number of light dots is not restricted. Thus, unlike frequency interpretation, it does not need $n \to \infty$maximum restriction conditions, but it has internal commensurability with frequency interpretation. Where visibility is better, there are more light dots, and the probability for light dots to appear is greater; where visibility is worse, light dots are less, and the probability for light dots to appear is less; when visibility is 0, no light dot appears, and the probability is 0. Also, visibility (distinction of vision) can be a concept of continuity, and be interrelated with wave. So, through probability visibility definition, number of times of a non-continuous event is transformed into the measurement of continuously changing space vision, which is a creative treatment of "visible image", the expansion of connotation of probability definition. Defining probability with visibility fits both great number counting and a single event. An electron appears somewhere on the screen and a light dot appears there, so the probability of the occurrence of electron there is 100%, its visibility is also 100%, and probability is 1. Where electron does not appear, the probability of the occurrence of electron is 0 and its visibility is also 0. Visibility of great number counting can be looked as integrated effects of single event; the probability of occurrence of single event cab be regarded as a special case of great number counting in single

event. The two cases supplement each other, without conflict. Axiomatic calculation can be made on visibility probability with the help of the property of curved surface. As straight surface changes to curved one, the visibility of curvature is also changing. There is no difference anywhere on surface and visibility is zero; there is curvature on surface and visibility exists; a surface is more curved and visibility is more distinct. The extent of curved surface is measured with curvature. The relation between visibility and curvature R is: curvature R is 0→straight→visibility is 0%; curvature R is infinite→point→visibility is 100%, which well corresponds to probability 0 or 1 of single event. While curvature R transits from 0→infinity, it happens to correspond to the occurrence of certain probability in great number counting (light point counting), a certain percentage from 0% to 100%. Calculation of probability does not need the ratio of integer to integer.

In theory, the communication of uncertainty and particle raises probability visibility interpretation; in experiment, communicating great number counting of light dots (frequency probability) with visibility and connecting it with geometrical image of curvature, the idea that space is the extension of substance is also expressed in physics. Particle and its own space are unified, which is two sides of the same thing. The space the human beings know is the most changeful. Straight space ($R=0$) and point $R=\infty$ are two extremes of substance extension; curved space exhibits more universality than straight one; wave space and its coherence are the important property of microscopic world, which is directly related to non-continuity of interaction of microscopic world. In different action mechanics and different theory structure, "substance of appearance" displays differently. So, the openness of "substance of appearance" is evident.

Reference

[1] Gui Qiquan et al. Logics of Opportunity & Adventure [M]. Beijing: Petroleum University Press, 1996:75-117.

[2] Wu Daqiu. Wu Daqiu Collected Works in Science and Philosophy [M]. Beijing: Social Science Press, 1996:34-55.

[3] Tan Tianrong. Reveal the Mystery of EPR Connection [M]. Tianjin Science & Technology Press, 1995:51-80.

[4] Ni Guangjiong et al. Modern Physics [M]. Shanghai Science & Technology Press, 1979:151-152,317-318.

[5] M. Jammer. Philosophy of Quantum Mechanics [M]. Translated by Qin Kecheng. Beijing: Commercial Press, 1989: 53-54,55,70.

[6] Zhao Guoqiu. On the Foundation of Reality Philosophy of Curvature interpretation of Quantum Mechanics // Science Technology and Dialectics [J]. 2001(5).

第五章
经典概率、量子概率与概率的可视度解释

我们把概率的置信度(主观)解释、确认度(逻辑)解释、频率(真实度)解释统称为概率的经典解释;而概率概念在量子力学应用中带来的变化称为量子概率。量子概率与经典概率在概念上有联系也有区别。借助于概率的"可视度解释",将概率定义合理地引到单个事件及波的干涉,可将量子力学概率解释与量子力学曲率解释联系起来,排除经验主义的纠缠,合理地解释电子的双缝干涉实验。

第一节　经典概率

一、概率的几种解释

(一)置信度解释[1]

概率的置信度解释又叫信念度解释或主观解释。代表人物是拉姆赛、德·芬内蒂和萨维奇(萨维奇称其为私人主义解释)。所谓置信度,是指特定个体对待特定命题真实性相信的程度。也就是概率是对个人信念合理性的量度。概率的置信度解释表明,事件本身并没有什么概率,事件之所以指派有概率只是指派概率的人头脑中所具有的信念证据。一方面,不同的人对同一事件的置信度不相同,因此,置信度是相对的;另一方面置信度又随个人的认识程度和所具有的知识状态的改变而改变,因此,置信度又具有可变性。置信度的可变性和相对性是概率主观解释的核心。

可以举例加深对概率主观解释的理解。赌博是常见的事例。某人下赌注,他的赌注到底下哪一边,下多少,是成功还是失败,只是下

赌注的人信念上的事，不需要涉及任何客观统计资料。这种成功与失败，其概率是主观上的估计，是个人对可几事件的置信度。这也是人们把这种概率叫主观概率的重要原因。主观概率要求每一个有合理信念的人不能自相矛盾，信念自始至终首尾一贯。这种作为信念合理性量度的主观概率尽管是观念性的，但仍然遵守概率演算公理，并符合经典统计力学的因果关系。

（二）逻辑解释（确认度解释）

对概率的解释，除主观解释之外，还有以鲁道夫·卡尔纳普为代表的逻辑解释。逻辑解释通过对可几事件确认度（确证度）的量度得到定义。确认度则是对可几事件的一种逻辑推理，也就是将归纳逻辑看作任意命题 H（假说）与证据 E 之间所具有的逻辑关系，即 E 对 H 的归纳支持度。这样，概率 $P(H,E)$（读作 H 对 E 的概率）的值，至少在原则上可以单值地定义。以气象预报为例。气象预报之前要收集气象资料（气象数据），然后，对气象资料进行分析。通过逻辑推理，推断明天“晴”或者“雨”，这一随机事件出现的概率。这里，所收集的资料（气象数据），并不一定与预测的随机事件“晴或雨”发生直接的联系，但逻辑上有关系，因此可在一定程度上作为可几事件出现的支持证据。例如，通过对气象数据的逻辑分析，得出明天下雨的概率是 80%。但这就必须注意，这个 80%要下雨只是逻辑推理的结果。它①不是事实，还没有到明天，②也不能理解为实际发生事件的一个相对频率，③更不意味着是可确认的。80%的概率总不能与事实相符，无论是否下雨，它只是一个确认度而已。看来，概率的逻辑解释中，概率既不是事实的，也不是可证实的，概率陈述和经验结果之间并不存在任何直接的必然联系。[2]它是通过资料之间的逻辑关系，对可几事件的一种预测。可几事件的概率本身是观念性的，但可几事件的出现受因果关系制约。

（三）频率解释

概率的频率解释又称频度解释或客观解释（真实度解释），是指一类特定事件 E 中，某一事件 H 出现的相对频率。精确定义是：被指派概率的数值 P，是一重复事件 H 的一个无穷系列 E 在长趋势中所表现的相对频率的极限值。其数学表达式是：

$$P(H,E)=\lim_{n\to\infty} m/n \tag{5.1}$$

其中：$0 \leqslant m \leqslant n, 0 \leqslant P \leqslant 1$，$m$ 是 H 产生的次数，n 是 E 的总次数。m、n 都是整数，在频率解释中，概率是整数与整数比的极限。必须注意，这里事件的“类”是形成概率的条件。“类”的选择不同，概率的值也就不同。[3]概率的频率解释无须假定“随机事件的无差异原理”，而是根据事件出现的客观状态，通过相对频率的极限计算随机事件出现的概率。所以，又称频度概率为客观概率。概率的频率解释也有其不足之处，就是当相对频率的极限不存在时，概率就无法定义。同时频率解释不适用于单个事件或假说。

概率的频度解释中相对频率与概率的关系可从下例得到说明。

投硬币，当 $n \to \infty$ 时，正面朝上的概率为 50%，但当 n 不是无穷大时，正面朝上的相对频率却是可变的。表 5-1 中是 A、B、C 三人投硬币的实验数据。根据相对频率的计算公式：

$$f_i = m/n \tag{5.2}$$

可计算相对频率。见表 5-1。

表 5-1　相对频率实验数据

实验者	实验总次数(n)	正面朝上次数(m)	相对频率(f_i)
A	4040	2048	0.5469
B	12000	6019	0.5016
C	24000	12012	0.5005

从表 5-1 不难看出，相对频率的数值并不正好等于 0.5，而是随着实验次数的增加，相对频率逐渐逼近极限值 0.5。这个 0.5，就是当$n \to \infty$时，投硬币正面朝上的概率。

概率的频率解释有缺点，也有优点。优点在于强调概率的客观性，将概率与科学实验相联系，断定客观世界有统计规律存在。但是我们仍然必须注意，客观概率也只是一种大数统计的规律性，它是一种知识，对单个事件不能定义。对单个事件，只能定义相对频率，而不能定义概率。而概率的“可视度解释”，却可以综合包容上述两方面的内涵，扬长而避短。在第四部分我们将详细论述。

二、经典概率的特征

(一)概率的知识性和单次随机事件的因果性

我们把概率的主观解释、概率的逻辑解释、概率的频率解释统称为经典概率。经典概率的重要特征之一，是概率的知识性和单次随机事件的因果性。概率表示一种数学知识，代表一类事物出现的统计规律，并且单次事件的出现受经典力学控制。概率的主观解释中，赌徒下赌注，完全凭的是主观判断。当然，他可能有他的依据，比如，他依据"无差异原理"和"庄家手的摇动姿势"等等。这是置信度形成的过程。但他的信念程度与骰子出现的点数没有必然的内在联系。因此，赌徒估计的概率，是他的一种信念程度，是主观的而不是客观的。只有当庄家揭盖子的时候，主观的概率才向客观的现实转化。这种转化不受主观制约，只受客观条件制约。随机事件的发生符合经典力学的因果关系。当然，主观可能与客观相符，也可能不符，相符概率是1，不符概率是0。一般地主观概率是(0,1)之间的一个百分比，而现实只有"是(1)"或"不是(0)"这两种情况。我们把这叫主观概率向客观现实的(0,1)突变。概率的逻辑解释也有类似的情形。天气预报中，气象数据与预报的结果之间是一种逻辑推理关系。说明天60%要下雨，那也是一种预计，是对各种气象资料综合分析得出的结论。这是概率的形成过程。它与明天是否下雨没有必然的内在联系。然而，真的到了明天，天气不管是"晴"还是"雨"，"天晴"则下雨的概率变为0，"下雨"，则下雨的概率变为1。真实的明天，下雨的概率还是在(0,1)之间突变的。天气预报"明天60%要下雨"，仍然是一种对天气了解的相应知识，它也存在一个主观向客观转化的过程，而且这种转化只受气候因素制约，而与人的主观判断无关。

概率的频率解释也不例外。虽然由频率解释得到的概率叫客观概率，这只是针对概率的形成而言的。客观概率是对大数统计规律性的量度，概率本身仍然是一种数学知识。定义式(5.1)中的 $n\to\infty$，是表明随机事件出现的概率伴随一个大数统计过程，即从具体到抽象的过程。因此，概率的形成求取过程，实际就是从单个物理实在向观念或知识上升的过程。掷硬币，正反面出现的概率各为50%，

也正是表明一种大数统计规律，是一种知识。通常我们比较注意概率形成求取过程，而比较不注意其反过程。所谓反过程，是指通过大数统计，我们知道了某类随机事件出现的概率后，再观察随机事件出现的过程。比如掷硬币，虽然我们已经知道了正反面出现的概率各为 50%，但此后的每次掷硬币，仍然只有两种确定的状态：要么正面，要么反面。用概率来表征，就是正面(或反面)出现的概率要么是1，要么是 0。而且，单次事件的出现受经典力学的条件控制。由此我们得出结论：如果把大数统计的分析归纳过程看作是由单一物理实在(0,1)向观念知识上升的过程；那么反过来，知道概率之后，再次观察单次随机事件发生的过程，也可以看作是由观念(知识)向物理实在(0,1)转化的反过程。不管概率的哪种解释，无论初始条件怎么复杂，如何不可预料，单次随机事件的出现，其物理机制总是受经典力学因果关系制约的。

(二)概率的叠加性

我们再来看看经典概率对子弹(以子弹取代电子)穿过双缝实验的描述。[4]如图 5.1 所示。图 5.1 中 A 是子弹发射源。第一步关闭缝 S_2，只开 S_1，得到子弹在屏 B 上的概率分布曲线 P_1；第二步关闭 S_1，只开 S_2，得到子弹在屏 B 上的概率分布曲线 P_2；第三步将 S_1、S_2 同时打开，得到的分布曲线是 P，而且

$$P=P_1+P_2 \tag{5.3}$$

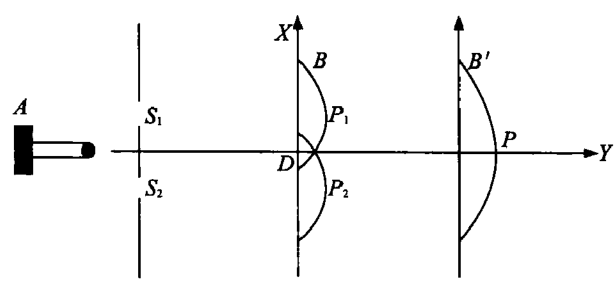


图 5.1 经典概率对子弹穿过双缝实验的描述

这表明经典概率符合叠加原理。

(三)概率的条件性

在概率的主观解释中，形成主观概率的个人，他的最基本的依据

是相信随机事件出现的“无差异原理”。比如硬币或骰子，这个“无差异原理”就是硬币和骰子的“材质均匀”。这实际上是主观概率出现的条件。如果硬币和骰子的“材质不均匀”，而且有人知道了这种“不均匀”，那么他所形成的主观概率肯定会与其他不知道的人不同。在概率的逻辑解释中，某一命题(事件)出现的概率，是通过其他命题(事件)与其之间的逻辑关系推断出来的。比如前面提到的天气预报，预报者掌握的气象数据不同，预报的准确度也就不同，掌握的气象资料越多，越全面，预报的准确度就会越高，对气象资料的掌握，当然就成了逻辑概率形成的条件。在概率的频率解释中，随机事件选取比较的“类”不同，概率也会不同。比如，抽烟得癌症的病人占全市人的概率，就与抽烟得癌症的病人占抽烟人的概率不同。同一个随机事件，选取比较的“类”(全市人与抽烟人)不同，其概率就不同。这里“类”的选取实际上是概率形成的条件。

一般地，若 R 是比 S_i 更强的条件，即满足 R 的事件都满足 S_i，在 S_i 条件下进行的 N 次随机实验中，有 N_R 次出现 R 事件，则在 S_i 条件下 R 事件出现的概率(概率)为[3]

$$P(R/S_i) = \lim_{n\to\infty} N_R/N \tag{5.4}$$

我们把既满足条件 A，又满足条件 R 的事件，称作“$R\cdot A$”事件。若在 S_i 条件下进行的 N 次随机实验中，有 $N_{R\cdot A}$ 次是 $R\cdot A$ 事件，则在 S_i 条件下，$R\cdot A$ 事件出现的概率(概率)为

$$P(R\cdot A/S_i) = \lim_{n\to\infty} N_{R\cdot A}/N \tag{5.5}$$

又，在 N_R 次出现 R 事件的实验中，有 $N_{R\cdot A}$ 次出现事件 A，因此在 R 条件下，事件 A 出现的概率(概率)是：

$$P(A/R) = \lim_{n\to\infty} N_{R\cdot A}/N_R \tag{5.6}$$

将(5.5)除以(5.4)得：

$$P(R\cdot A/S_i)/P(R/S_i) = \lim_{n\to\infty} N_{R\cdot A}/N_R \tag{5.7}$$

比较(5.7)、(5.6)式得：

$$P(A/R) = P(R\cdot A/S_i)/P(R/S_i) \tag{5.8}$$

(5.8)式中只有条件 $R=S_i$ 时才有

$$P(A/R) = P(R\cdot A/S_i) \tag{5.9}$$

否则

$$P(A/R) \neq P(R \cdot A/S_i) \quad (5.10)$$

(5.10)式表明经典统计条件的变化，同一事件出现的概率(概率)将发生变化。这种变化不是前面提到的从观念到物理实在(0,1)的变化。从观念到物理实在的转变，其背后有着更深层的力学边界条件的限制，受因果关系制约。了解这一点，对理解量子概率有十分重要的意义。

第二节　量子概率

在海森伯提出量子力学矩阵形式(1925 年)后不久，薛定谔提出量子力学的波动形式(1926 年)。在薛定谔的波动方程中波函数 ψ 描述了电子的运动状态。对波函数 ψ 最先给出明确意义的是玻恩。1926 年玻恩在一篇题为“论碰撞过程的量子力学”的论文中指出：$|\psi|^2 d\tau$量度了在空间体积元 $d\tau$ 中找到粒子的概率。这就是玻恩的波函数 ψ 的概率解释。按玻恩当时的理解，电子等微观粒子被设想为古典意义下的质点，它在每一时刻既具有确定的位置，又具有确定的动量。[5]“波动力学并不对粒子碰撞之后的精确状态是什么?”做出回答，而只是回答了“碰撞之后处于某一确定状态的概率是多少?”这一问题。在量子力学中，对一切事件所能说的只能是某事件以什么概率出现，这个概率就取决于概率波的波函数 ψ 的平方(玻恩在一开始没有强调“平方”，后来做出了改正)。电子波是按概率变化的波。玻恩的概率波克服了薛定谔等人提出的物理实在波的一些困难，如波包扩散等等。玻恩获得了成功。但是，把玻恩原始经典意义下的概率解释(由于没有分清“概率”与“概率幅”的区别)用来说明诸如电子单缝衍射及双缝干涉之类的现象时，却遭到了令人沮丧的失败。电子波的概率不是经典意义下的概率，与电子对应的概率波不遵从前面提到的经典概率叠加原理，也就是不遵从经典因果律。量子概率具有波的干涉效应。图 5.2 则是对这种干涉效应的说明。

在图 5.2 中电子通过双缝 S_1、S_2 之后，不是形成为图 5.1 中的叠加曲线 P，而是形成了干涉图样 P'。实验可以在电子流极弱的情况下进行，使得一次只有一个粒子通过仪器。从数学分析可知每个粒子所带有的波同它自己发生干涉。“数学波”的干涉可以通过粒子

在屏幕上的物理分布显示出来。这意味着电子波含有一种真实的物理作用。因此,波函数必定有某种物理实在性,量子概率不应是经典概率意义下的知识性的东西,也就是说不是经典意义下的知识波——数学波。这是量子概率与经典概率的一个重大区别。

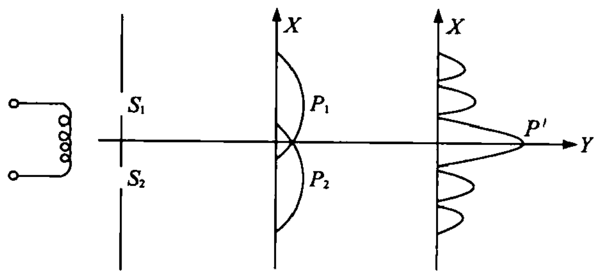


图 5.2　电子双缝干涉实验

按照玻恩对量子概率经典方式的理解,$|\psi|^2d\tau$ 应是体积元 $d\tau$ 中粒子出现的概率。根据概率频率解释含义,$|\psi|^2d\tau$ 应体现为某个整数与另一个整数之比。即电子出现在体积元 $d\tau$ 中的次数(整数),与出现在体积 τ 中的次数(整数)之比。然而,任何一个具体的波函数,都无法体现概率的整数比形式。这也是将波函数理解为概率的另一个巨大障碍。电子双缝实验表明量子概率不具有经典概率的叠加性,量子概率不同于经典概率,不遵从经典力学作用规律。量子概率具有相干性。"上帝掷骰子",既可以掷出①点,也可以掷出②点,还可以掷出①+②同时存在并有相干性的状态。数学分析还表明电子波是自身和自身干涉,一个电子能同时通过双缝,这是经典力学无法理解的。量子概率应有不同的力学基础。然而电子在屏上的落点却又具有经典概率的品质。一个电子落在屏上的 A 处,它就不能落在屏上的 B 处(由亮点显示),形成量子概率的每一个元素——电子,其落点,仍然具有(0,1)、(1,0)的决定论属性。

如何解决量子概率既有与经典概率不同的本质,而在从概率向物理实在的转化中又具有经典概率的(0,1)特征呢?这真是对人类智慧的检验。物理学和哲学家们有两条思路:第一条思路是电子波不是数学波(概率波),而是物理波。德布罗意、薛定谔、马德隆等人是其代表人物,爱因斯坦是这一思路方式的积极支持者。第二条思

路是电子波是概率波，因为电子在屏上的落点是统计性的。但波函数不能完全理解成一种数学的虚构，而应赋予一种潜在的物理实在性。因为纯数学波的干涉不能产生真实的物理作用。人们相信只有真实的物理相互作用，才能产生真实的物理效应——干涉图样。哥本哈根学派是这一认识路线的代表。海森伯认为是一种“潜能”和“趋势”在控制量子概率的发生。它是一种处于物质与观念精神之间的中间层次的实在。量子力学中的概率波被理解成由“潜能”或“趋势”控制着的概率波。这就是说，决定量子概率的深层基础不是经典牛顿力学和相对论力学，而是处在“物质实在”与“观念精神”之间的中间层次的“潜能”或“趋势”。它被看作是一种新型的“物理实在”。“潜能”和“趋势”的力学基础是什么？不明确。但是，海森伯在试图对电子通过威尔逊云室的路径做出概率解释时，赋予了微观粒子动量和位置的不可确定性属性，而正是这个不可确定性属性在电子双缝实验中，将“潜能”和“趋势”做了具体化。所以海森伯说：“这种不确定性正是量子力学中出现统计关系的根本原因。”这样，量子概率的出现，就不需要经典概率那样的不可知的力学边界条件，其统计性的出现，由微观粒子自身的不确定性得以完成。[5]

经典概率形成的原因是事件发生的力学初始条件的不可控制性，但事件的发生仍然遵循牛顿力学和相对论力学的基本规律。量子概率形成的原因是微观粒子自身本质上具有动量和位置的不可确定性。微观世界的这种“不可确定性”，是粒子自身的属性，它不需要外在的基础。相反，又正是这种“不可确定性”，奠定了微观世界物质运动的“新”的力学基础。这就是正统诠释的所谓“量子力学”的本质。“不可确定性”真的是微观粒子自身的属性？在微观世界中，微观粒子真的都患有米尼米氏多动症？近一百年来围绕量子力学正统诠释出现的一系列悖论，量子力学中波函数是物理波还是数学波的争论仍然没有完结。就笔者的研究所知，至少还有如下一些问题值得讨论。

第一，薛定谔方程是建立在经典电磁学基础上的，因此，薛定谔方程是决定论的。彭罗斯把这称作 U 过程。一个位置和动量不能同时确定的电子，其运动方程的演化却是确定的？描述电子运动状态的方程不需要电子同时具有确定的动量和位置？电子没有确定的

位置和动量，能有确定的状态？

第二，海森伯的"不确定性"，只能为电子在屏上落点的统计性或者波函数的概率性，提供一个人为约定的理论基础，它是公理性的。不确定性并没有解决电子波的干涉问题。电子通过双缝表现出波的干涉的物理机制还没有明确。于是又引出了一个电子落点的统计性是在测量的一瞬间完成的问题。彭罗斯把这叫 R 过程。玻尔认为电子的波性和粒子性是设计的仪器系统赋予电子的，想设计电子是波的仪器系统，它就表现出波性；想设计出电子是粒子的仪器系统，它就表现出粒子性。电子的波粒二象性属于现象形态，被看作是人类经验的产物。电子波纯属经验的。

第三，解释薛定谔方程需要电子遵从经典力学；解释电子通过双缝的干涉效应，表明电子不遵从经典力学，需要赋予电子自身的不确定性属性。为了解释微观物理现象，一个电子就这样被人们在决定论和非决定论中推来推去，无所适从。人的认识也因此变得越来越糊涂，甚至痛苦不堪。人类的智慧真的已经穷尽？对微小的电子一筹莫展？不是的。

量子力学曲率解释是试图解决这一问题的金钥匙。

第三节　概率的可视度解释(讨论篇)

因为曲率 R 表示曲面弯曲的程度，曲率越大，粒子性越清晰，曲率越小，粒子性越模糊。因此，曲率 R 的大小可表示电子粒子性的"可观察程度"。$\Delta p \neq 0$、∞，$\Delta x \neq \infty$、0，$R \neq 0$，空间有弯曲，有"可视度"，粒子性出现。R 越大，曲率越大，可视度越大，粒子性越强。$R=\infty(\Delta p=\infty, \Delta x=0)$，电子变成质点，有准确的位置，可视度100%；$R=0(\Delta p=0, \Delta x=\infty)$，曲率为 0，粒子性消失，不可视，"可视度"为 0。

曲率 R，通过"可视度"概念与"概率"也有很好的对应。概率的变化可以"翻译"成曲率的变化。对概率解释而言，测不准关系中，Δp 越大，Δx 越小，电子出现的概率就越大；Δp 越小，Δx 越大，电子出现的概率就越小。而电子出现概率的大小，也可以认为是电子"可看见程度"的大小。概率大，则是在该处"可看见的程度"大，概率小，

则是在该处"可看见的程度"小。概率 ρ 、Δx 及可视度的关系是：

$$\rho \propto \frac{1}{\Delta x} \propto \text{可视度}$$

对曲率解释而言，测不准关系中，Δp 越大，Δx 越小，曲率 R 就越大，粒子性越强，可视度越大；Δp 越小，Δx 越大，曲率 R 就越小，粒子性越弱，可视度越小。曲率 R 、Δx 及可视度的关系是：

$$R \propto \frac{1}{\Delta x} \propto \text{可视度}$$

所以 $$\rho \propto R \propto \text{可视度}$$

ρ、R 、可视度三者通过测不准关系中的 Δx（或物质波波长 λ），形成了有机的内在联系。

为了解决量子力学解释中的矛盾，现在我们有必要而且有可能对概率解释的内涵作适当扩充。

在微观世界，我们的研究对象不是点粒子，而是有一定的几何形象。但是我们可以通过点粒子抽象将粒子的几何属性转化成点粒子的不可确定性；或者反过来说，我们也可以把点粒子的不可确定性，还原成粒子的几何属性。如果粒子的几何属性用曲率来表征，那么量子力学概率解释就自动转变成了量子力学曲率解释[6]。粒子的几何形象是可视觉的，当把粒子表面的弯曲程度作可视度的一种量度时，微观粒子本质上具有不可确定性的属性就被抽掉了，并且理论上也恢复了本体论的地位。这是质点抽象建立理论的一头。

在实验检验的另一头，光点在屏上随机地出现。光点散落得越多的地方，可视的程度——可看见的清晰程度越高；光点散落越少的地方，可视的程度越低；没有光点的地方，看不见光点，可视度为零，不可视。这里所说的可视度是大数统计规律，光点的多少不受限制，因此，它不需要像频率解释那样需要 $n \to \infty$ 的极限约束条件。然而，它却又与频率解释有内在的通约性。可视度高的地方光点多，光点出现的概率也高；可视度低的地方，光点少，光点出现的概率也小；可视度为 0，光点不出现，光点出现的概率为 0。而可视度，即可看见的清晰程度，可以是一个连续的概念，可以与波联系在一起。因此，我们通过概率的可视度定义，又把一个非连续的可几事件的次数，转化成了可连续变化的空间视觉的量度。这是对"影视图像"的一种创造

性处理，无疑是扩大了定义概率的内涵。用可视度定义概率，既可适用大数统计，又可适用于单个事件。一个电子出现在屏上的某处，某处出现一个光点，电子在这里出现的概率为 100%，那么可视度也就是 100%，也就是概率为 1。电子没有出现的地方，电子出现的概率为 0，而可视度也是 0。大数统计的可视度，可看作是单个事件的综合效应；单个事件出现的概率，可看作是大数统计在单个事件上的特例，二者相辅相成，没有矛盾。可视度概率可以借助曲面的性质进行公理化运算。一个曲面，由平直向弯曲转化，可视度也在变化。平面到处无区别，可视度为零；平面弯曲，则有可视度；曲面越弯曲，则可视度越高。曲面的弯曲程度由曲率来量度。可视度与曲率 R 的关系是：曲率 R 为 0→平面→可视度为 0%；曲率 R 为无穷大→点→可视度为 100%。这正好对应单个事件的 0 概率和 1 概率。曲率 R 由 0→无穷大过渡，刚好对应大数统计（光点统计）某一概率的出现，它是 0%到 100%之间的某一个百分比。概率的计算不需要整数与整数之比。

将理论一头的不可确定性与粒子的形象沟通，引出概率的可视度解释；将实验一头的光点的大数统计——频率概率与可视度概率沟通并与曲面的几何形象相联系，空间是物质的延展性又有了物理体现。粒子与粒子占有的空间是统一的，是一个问题的两个方面。人类认识的空间是变化多端的。平直空间（$R=0$）与点 $R=\infty$，只是物质延展性的两种极限状态；弯曲空间比平直空间更具有普遍性；波动空间及其相干性是微观世界的重要特征，它与微观世界相互作用的非连续性直接相关。不同的作用机制，不同的理论结构，“现象实体”的表现不相同，“现象实体”的开放性是显而易见的。

参考文献

[1] 桂起权，等. 机遇与冒险的逻辑[M]. 北京：石油大学出版社，1996：75-117.

[2] 吴大猷. 吴大猷科学哲学文集[M]. 北京：社会科学出版社，1996：34-55.

[3] 谭天荣. 揭开 EPR 关联之谜[M]. 天津：天津科学技术出版社，

1995:51-80.
[4] 倪光炯,等.近代物理学[M].上海科学技术出版社,1979:151-152,317-318.
[5] (美)M.雅默.量子力学的哲学[M].秦克诚,译.北京:商务印书馆,1989:53-70.
[6] 赵国求.论量子力学曲率解释实在论哲学基础//科学技术与辩证法[J],2001(5).

Chapter 6
Quantum Measurement in Quantum Mechanics Curvature Interpretation

6.1 Quantum Mechanics Curvature Interpretation & Two-Slit Experiment

In the depth of atom, the "image" constructed for microscopic object through matter wave wavelength $\lambda\!\!\!^{-}$(curvature radius) cannot be ignored. Mass point abstract principle of Newtonian mechanics, neither applicable nor imitable, cannot be used to research electron trajectory motion. Motion law of object should be described with wave function which reflects space structure of object. Electron wave is curvature wave; wave is real and mass point is virtual. The transmission of curvature wave is that of substance wave. Electron wave produced from atom will continue to behave as wave, or it may show its macroscopic corpuscular property when passing two-slit or meeting similar production conditions.

6.1.1 Standard Copenhagen interpretation and Two-Slit Interference Experiment

According to standard Copenhagen interpretation, in two-slit experiment, if particle is confirmed in measurement to have passed any slit, particle property of wave particle duality is emphasized and undulatory property complementary with corpuscular property

is expelled, so interference stripe will disappear. Specifically, from Werner Karl Heisenberg uncertainty principle: it is known exactly that particle passes through path A (if slit B is blocked), which means that particle location is completely determined in the direction vertical to A. If accuracy of location measurement reaches Δx, it is known from uncertainty principle:

$$\Delta p_x \cdot \Delta x = \hbar \tag{6.1}$$

that the measurement will produce perturbation motion of $\Delta p_x = \frac{\hbar}{\Delta x}$ on momentum in the direction vertical to A so as to interfere the location of particles reaching the screen, change wave phase position and cause the disappearance of interference fringe.

The theoretical foundation of standard Copenhagen interpretation relied on Niels Bohr complementation principle: substance motion possesses double attributes of particle and wave, but in the same experiment the two exclude each other. Uncertainty principle is an important cause that leads to the quantum decoherence of tested system. [1]

The interpretation of Copenhagen School to two-slit interference experiment is not satisfactory, the main reason for it is:

① Experiment indicates, a particle itself may cause interference, how can single "electron itself" pass two-slit? A particle can pass two slits at the same time?

② Probability wave is mathematical wave, while electron wave possesses real physical function, and then, how can we deal with the relation between mathematical wave and physical reality?

③ Werner Karl Heisenberg believed a kind of "potential" and "tendency" control the occurrence of quantum probability, which is like a "substitute" of "electron itself" on its "middle level", and then, what is the mechanical basis for the transition of "probability" of middle level to "reality"?

④ The electron that passes through two-slit follows the evolu-

tional law of quantum probability and possesses coherence. On the contrary, the classical electron that passes through two-slit follows the evolutional law of classical probability and has no coherence. In quantum measurement, if electron changes from obeying quantum probability to obeying classical probability, then, what is its physical attribute when it is turned from wave to particle or collapse of wave packet?

⑤ The important conditions for the diffraction of light and electron are: (a) Independent interference wave sources; (b) Constant phase difference; (c) Slit width Δx and wavelength of light and electron λ can be compared. If slit width Δx is much bigger than the wavelength of light and electron λ, diffraction and interference will disappear automatically. At this time, when electron changes from obeying quantum probability to obeying classical probability, is this also automatic decoherence? What is the difference between this decoherence and that caused by quantum measurement in physical mechanism?

Here we only list a few.

In a word, the answers of Copenhagen School to the above questions are hardly satisfactory, or we may say that they did not give answers in physics but tried to avoid the physical investigation in the real life by resorting to philosophical principle.

6.1.2 Curvature Interpretation of Quantum Mechanics & Two-slit Interference Experiment

6.1.2.1 Electron wave preparation before two-slit

We have already proved that, only when the "image" prepared for electron in the depth of atom is not ignorable, can the electron prepared from atom be expressed in wave (because the theory of electron wave is turned to classical electron theory when energy level n shows a tendency of being infinite). Because this moment background space and microscopic object cannot be separated, in-

stead of being able to study the trace of "point electron" we can only study the image structure attribute of "electron's" space and the change of "visibility" thus caused, through wave function. In quantum mechanics curvature interpretation, ψ is curvature wave, describing the law of changes of the "image" constructed for electron; dv is volume element described by curvature; and space V has physical sense. If the electron wave passing through two-slit is marked ψ, ψ is real and "point electron" is virtual. Albert Einstein called electromagnetic field "ghost field"; field is virtual and photon is real. Electron wave, before entering two-slit, can be regarded as the electron that has just prepared from atom; field is real and point electron is virtual, also named "ghost electron". And only when it meets the condition similar to primary preparation condition ("image" is non-ignorable and possesses the property of sudden change), can the wave field of this substance continue to exhibit vibration and possess coherence, and otherwise it may exhibit macroscopic corpuscular property.

6.1.2.2 Two-slit identifies wave and particle

"Two-slit" is a kind of identification device of microscopic object undulatory property or corpuscular property of light and electron. If slit width is Δx, and wavelength of matter wave passing through two-slit is λ, from uncertainty principle we get:

$$\Delta p_x \cdot \Delta x = \hbar \tag{6.2}$$

From Louis de Broglie relation we get:

$$p \cdot \lambda = \hbar \tag{6.3}$$

Because $\Delta p_x \leqslant p$, we have:

$$\Delta x \geqslant \lambda \tag{6.4}$$

Equation (6.4) indicates, in two-slit experiment, slit width Δx is bigger than matter wave wavelength λ, which is the basic condition that two-slit produces wave interference.

Experiment shows, $\Delta x \ll \lambda$ and $\Delta x \gg \lambda$, single slit diffraction and two-slit interference cannot occur. Only when Δx is about the

same size as λ and not too bigger than the latter, can wave coherence occur, which is the physical sense of equation (6.4). Now, we can hold it that, the effect of "image" constructed for electron with wavelength λ before two-slit cannot be ignored yet when we discuss the issue of "image" in two-slit; microscopic object and background space cannot be locally separated. What is from inside the two-slit is still electron wave, while two-slit interval becomes the mutant area of two energy levels, and two-slit is the wave source of interference wave.

If $\Delta x \gg \lambda$, the effect of "image" in the slit can be neglected, and light and electron conduct as point particle according to mass point abstract principle in Newtonian mechanics; if $\Delta x \ll \lambda$, light and electron bounce in the form of particle, which is the conclusion of the experiment.

Obviously, if we "design an instrument that can produce either wave or particle", as Niels Bohr put it, its key point is whether the "image" constructed for microscopic object can be ignored in specific environment.

When $\Delta x \geqslant \lambda$, wave in slit has the nature of substance. And particle is virtual, the "ghost" of real electron, so it does not matter which slit the "ghost" electron passes, thus solving the problem that an electron passes two slits simultaneously.

6.1.2.3 Wave interference and decoherence after two-slit

In quantum mechanics curvature interpretation, the size of "image" we construct for microscopic object and the probability of finding "virtual point particle" in "image" is in inverse ratio, probability and the curvature of curved surface that forms "image" is in direct ratio, and pre-two-slit wave function ψ_1 and ψ_2 after two-slit possesses double attributes: it is either curvature wave or probability attribute. The probability of point particle dots on screen is determined by the probability attribute of wave function; the transition of virtual point particle to real point particle is determined by

the space attribute of wave function. In quantum measurement, the interaction between instrument and tested system (the introduction of macroscopic continuous effect) is the important condition of the transition of "discretized wave form" to "local particle form". Obviously, this transition will go through a process, and mutation is impossible. If the effect of introduction is discontinuous effect, mutation may occur between pre- and post states, forming new superposition state, new interference term. But in experiment, new interference cannot be seen and what is seen is the disappearance of interference. It is the involvement of continuous effect that brings about the "self-entanglement" of wave function and forms "self entangled state". "Self-entanglement" of wave function is self-entanglement of "image", reflecting how mutation wave function before measurement in interaction is transformed into continuous wave function after measurement, and this is decoherence process. In new environment, if "image" can be ignored, "virtual particle" has "substance" attributes. Without the effect of quantum measurement, without image "self-entanglement", particle cannot resume its macroscopic original "image". Therefore, post two-slit measurement of wave function (interference of continuous effect) is the important physical factor of transition of wave to particle.

The fact that a particle passes two-slit and shows dots on screen is the result of "self-interference", "self-entanglement", and "automatic decoherence" of particle.

All in all, microscopic object in the depth of atom cannot be separated from the background space of its environment, and object must be described by wave function that reflects space structure. Wave is real and mass point is virtual. Catastrophe between energy levels is the basic cause that independent interference wave sources are formed and coherent property is caused. We cannot deal with natural appearance at different levels of cognition in fixed and unchangeable thinking ways, for the attempt is in vain to integrate

substance prospects of the world in a single thinking way. What quantum mechanics and theory of relativity describe is the problems of different levels of cognition; they can be interconnected, their logic association can be found but not replaced. In the interpretation of two-slit experiment, quantum mechanics curvature interpretation satisfies the requirement of Einstein's theory of reality and keeps to the basic thoughts of Niels Bohr. Quantum mechanics curvature interpretation has found a good logic "interface" between quantum mechanics and theory of relativity.

6.2 Schrödinger's Cat & EPR Ideal Experiment

Quantum state entanglement is probability entanglement, or probability width entanglement, in probability interpretation. Microscopic object "space form" entanglement is also included in curvature interpretation. Also, the entanglement brought about by Albert Einstein's "interaction" only provided a macro and microscopic transitional mechanism. When the essence of micro and macro mechanism is clearly distinguished, quantum mechanics curvature interpretation provides a new road of cognition in eliminating Schrödinger's cat and EPR paradox, so that more detailed quantitative analysis will be made.

6.2.1 Schrödinger Cat Paradox

6.2.1.1 Origin of Schrödinger cat paradox

It is hoped that quantum mechanics is the universal theory on the whole universe, which describes not only microscopic physical system but also the macro measurement instrument which observes this system. It is also hoped that the same as tested system, instrument follows the evolutional law of quantum probability. Von Neumann and Alfred Lothar Wegener was the first to put forward the quantum measurement theory which tries to include instrument

and tested system. In the theory of Von Neumann, through the interaction between system and instrument, the system and instrument were regarded as the whole that followed quantum mechanics evolutional laws; when the whole was reduced to the part of tested system, quantum decoherence or the appearance of collapse of wave packet was revealed.

Von Neumann's theory had a serious flaw. Because he did not fully consider the macro property of instrument, Von Neumann had to introduce a series of endless instrument chain so as to realize collapse of wave packet, but in the end he still needed helps from outside the system, such as the thoughts of observers, God or the human beings. The last instrument was made to produce collapse of wave packet to realize quantum decoherence successively.

Von Neumann's idea was: to assume interaction between macro instrument and micro tested system, and only change the state of the instrument. We can "read" the state of the system from instrument state.

Schrödinger was the earliest to question the above theory of measurement. In 1935, Schrödinger suggested a hypothetical experiment, in which he imagined: a pitiful cat was shut in a sealed cage and in it was also a bottle which contained poison. The bottle was controlled by an atomic radioactive device. The probability is equal whether atom decayed or not within an hour. If atom is in excited state $|\uparrow\rangle$, the bottle is excellent without damage and the cat is alive (not killed); if atom transits to ground state $|\downarrow\rangle$, together with the release of photon, it starts a small hammer to break the bottle, thus releasing the poison which then kills the cat.

According to the interpretation of quantum mechanics on wave function, $|\uparrow\rangle$ and $|\downarrow\rangle$ are both probability waves, reflecting electron's transition probability at energy levels. From the principle of superposition state, atom may be in superposition state of $|\uparrow\rangle$ and $|\downarrow\rangle$:

$$|\psi_{atom}>=\alpha\,|\uparrow>+\beta\,|\downarrow>$$
$$|\alpha|^2+|\beta|^2=1 \tag{6.5}$$

Equation(6.5)indicates, atom may be in a probable state that either releases photon or not. If the atom is the cat Schrödinger indicated, "atom cat" may be in a "neither dead nor living" state.

Because quantum mechanics is regarded as universally applicable, macroscopic cat may be described with wave function of quantum mechanics, and the cat also possesses the evolutional law of quantum probability, or coherence. If |alive>and |dead> are two forms of energy eigenstate of cat, then:

$$|\psi_{cat}>=\alpha|alive>+\beta|dead> \tag{6.6}$$

As for the compound system of macroscopic "cat" plus microscopic "atom", "cat + atom" $|\psi_{compound}>$, then:

$$|\psi_{compound}>=\alpha|living\ cat>|\uparrow>+\beta|dead\ cat>|\downarrow> \tag{6.7}$$

Equation(6.7)indicates, in "atom plus cat" cage, cat may actually be in a "neither living nor dead" state.

According to Copenhagen interpretation of quantum measurement, the fate of the cat in the cage does not depend on the "objective existence" before opening the cage but on the "observation" after opening it. In the blink of an eye as the cage is opened, a man can let a "neither living nor dead" cat collapse to the real "living" or "dead" state (the essence is that "observation", human thinking effect, realizes the transition of quantum probability to macroscopic classical probability). It is obviously unreasonable that the human consciousness determines the cat's fate, which is the origin of Schrödinger cat paradox.

6.2.1.2 Decoherence of macroscopic object

After he discussed the above paradox from the visual angle of macroscopic object decoherence, Prof. Sun Changpu believed: In our discussion, the fate of macroscopic cat only represents two collective states; the so-called "macroscopic cat" means that the "cat" is made up of many microscopic particles. Therefore, the complete

description of Schrödinger cat state must contain infinite internal microscopic degree of freedom and not roughly simplified as:

$$|\psi\rangle=\alpha|\text{alive}\rangle+\beta|\text{living}\rangle \tag{6.8}$$

Its correct form should contain the internal state corresponding to death and living $|D_j\rangle$, $|L_j\rangle(j=1,2,3\cdots\cdots N)$, that is:

$$|\psi\rangle=\alpha|\text{alive}\rangle\otimes\prod_{j=1}^{N}|L_j\rangle+\beta|\text{dead}\rangle\otimes\prod_{j=1}^{N}|D_j\rangle \tag{6.9}$$

At this time, if talking about the cat's fate without considering how its internal is, cat's reduced density matrix should be applied:

$$\begin{aligned}P&=\mathrm{tr}_{\mathrm{in}}|\psi\rangle\langle\psi|\\&=|\alpha|^2|\text{alive}\rangle\langle\text{alive}|+|\beta|^2|\text{dead}\rangle\langle\text{dead}|\\&\quad+(\alpha^{*}\beta|\text{dead}\rangle\langle\text{alive}|\prod_{j=1}^{N}\langle L_j|D_j\rangle+h\cdot e)\end{aligned} \tag{6.10}$$

Because any one normalization state $|\langle L_j|D_j\rangle|\leqslant 1$, when $N\to\infty$, decoherence factor $F(N,t)=\prod_{j=1}^{N}\langle L_j|D_j\rangle$ will probably tend to zero. Macroscopic Schrödinger cat coherence superposition will lose its coherence in very short time of evolution. [2]

Obviously, the purpose that Prof. Sun rewrote cat wave function: transition from equations (6.8) to (6.9) was actually creating transitional condition for cat's "pure quantum state $\xrightarrow{\text{to}}$ mixed state $\xrightarrow{\text{to}}$ classical probability state". In his interpretation, cat embodied the transition of quantum probability to macroscopic classical probability, and its triggering condition was "when $N\to\infty$, decoherence factor $F(N,t)\to 0$; or as one of many internal state component, $|L_j\rangle$ and $|D_j\rangle$ were changed to orthogonal, internal product was equal to zero". Although it eliminated objective idealism (God), on one hand, it left room for coherence (the existence of infinite oscillation process), and, on the other hand, added an artificial arrangement: $|L_j\rangle$ and $|D_j\rangle$ are turned to orthogonal.

In fact, in Schrödinger's cat paradox, the change of the conditions of hammer or bottle is not equal to the change of atom decay

condition and there is no macroscopic hammer or bottle in |strike>+|not strike>, |break>+|not break> mutative superposition state. Macroscopic hammer, bottle and poison still need a process of decoherence, or macro real effect will not be realized. And this still needs to construct Professor Sun's "the entanglement of macro collective state and internal state", or transition from quantum probability to macro classical probability will not be able to be realized. And poison state (pure quantum state) will not return to macro real effect state. So it would not do even if the cat ignored "collective spirit" and returned to real world alone through decoherence, following Prof. Sun's thought. Let alone "the entanglement of macro collective state and internal state" that constructs hammer and bottle. Automatic decoherence in Prof. Sun's thought may be even more difficult than "cat".

6.2.1.3 Schrödinger cat in quantum mechanics curvature interpretation

In fact, the coming into being of Schrödinger cat paradox is not that cat's "infinite internal micro degree of freedom" is ignored, but that the essential differences between micro discontinuous effect and macro continuous effect and between microscopic quantum probability and macroscopic classical probability are mixed, and that wave function that agrees with the evolutional law of quantum probability in microscopic world is applied to macroscopic object undistinguished. Quantum mechanics believes that, although quantum theory is universally applicable in macroscopic world and even cosmic world, when it is connected with human macroscopic experience levels, we cannot ignore the usability of electron appearance on the logic basis provided by macro experience, nor can we ignore the essential differences between quantum appearance and macro appearance. Compared with dice casting, micro dice may reveal point "1" or point "2", even simultaneous points "1"+"2" and additional coherent items while macro dice can only show "1" or "2"

but no coherent item.

Careful analysis reveals that, Schrödinger cat ideal experiment is made up of two components of different natures: decayed atom which agrees with the evolutional law of quantum probability ($\hbar \neq 0$), possessing coherence, and macro components including hammer, bottle, poison and cat, which agree with the evolutional law of macro classical probability ($\hbar = 0$), possessing no coherence.

In atomic world, the acceptance and release of energy is discontinuous, portion by portion, thus interaction is discontinuous between energy levels. Catastrophe between energy levels provides physical basis for independent interference wave sources, wave function orthogonality and linear superposition. The wave function of atom in microscopic world agrees with the evolutional law of quantum probability, with coherence, superposition state either decay or not decay $|\psi_{atom}\rangle = \alpha|\uparrow\rangle + \beta|\downarrow\rangle$ is the solution to the equation.

In macroscopic world, if the changes of hammer, bottle and cat in the experiment are all continuous, without the concept of energy level transition, interaction is continuous between energy levels. No catastrophe exists whether the hammer "moves" or "stays still", bottle is "perfect" or "broken", and the cat is "dead" or "alive". Self continuous effect (with or without the effects of environment) and disappearance of independent interference wave sources enable macro objects to automatically produce decoherence, automatically accomplish quantum measurement, and realize the transition of quantum probability to macro probability. And this is the decoherent mechanism of macroscopic objects.

Therefore, macro hammer, bottle and cat can be simplified to the motion of macroscopic mass point. Location and momentum may exchange and still possess the same eigenfunction. Their movements are of determinism, following the evolutional law of macro classical probability, without wave interference effects. $|\text{movement}\rangle + |\text{no movement}\rangle$, $|\text{sound}\rangle + |\text{broken}\rangle$ and $|\text{dead}\rangle + |\text{alive}\rangle$

mutative superposition state does not exist. [3]

Thus, we believe that the sources of Schrödinger cat paradox lie in the following aspects:

① "Atomic cat" and "macro cat" have completely the same quantum probability properties. In fact, owing to the automatic introduction of macro continuous effect, self-entanglement enables "macro cat" "automatically" to become decoherent. Because of this self-disappearance of macro objective coherence, "macro cat" is to follow the evolutional law of macro classical probability. "Macro cat" has no |dead>+|alive>mutation superposition state.

② Neglecting the first aspect, and based on Von Neumann hypothesis, Schrödinger put into the evolutional category of quantum probability the atom decay, the hammer's movement, bottle broken or not, cat dead or alive——a pot of "quantum soup" in the cat cage. It is mal-position of quantum measurement to regard "cage-opening action" as the transitional condition of "quantum probability" to "macro classical probability".

③ The way to correct Schrödinger cat paradox is to change "cage-opening action" to decayed atom, to make atom decoherent, and transit quantum probability to macro classical probability (quantum measurement is to occur here). Electron wave and light wave lose coherence and change to real electron and photon, plus automatic decoherence of macro cat in self-entanglement, which eases Von Neumann hypothesis crisis. In above-mentioned Schrödinger cat cage, hammer's movement, bottle's condition, cat's fate all follow the evolutional law of macro classical probability, which belongs to determinism and is not against macro classical probability. When the cage is open, the cat is either dead or alive, whether you see it or not.

This is the detailed analysis of quantum mechanics curvature interpretation to Schrödinger cat paradox.

6.2.2 EPR Paradox

In 1935, Einstein, B. Podolsky and N. Rosen jointly published a short essay, in which they criticized the annotation of the basic principle and concept of orthodox quantum mechanics. The issue the essay pointed out was simplified as EPR Paradox. EPR essay has two conclusions:

① The description of quantum mechanics on "physical reality" is not perfect. Albert Einstein held on to determinism, opposing to "uncertainty principle", believing "God would not cast dice".

②The theory of quantum mechanics is not compatible, which in fact involves multi-particle system entangled state, expressing as "non-locality" in quantum mechanics. However, what Albert Einstein persisted in was "locality", that is, non-existence of information spreading of super velocity of light.

Albert Einstein's definition of "physical reality" is as follows:

"If we can definitely predict the value of a physical quantity in condition of no interference on the system, this physical quantity corresponds to a main factor of physical reality." The target physical theory describes is "physical reality", and in Newtonian mechanics this physical reality is "mass point". Physical reality is determined by several main factors including energy, momentum, location, and time. Albert Einstein required that, in physical theory, "physical quantity" and "physical reality factors" must correspond to each other one by one with determined value, or the theory is not perfect. [4]

According to the above definition, Albert Einstein produced a one-dimension quantum state:

$$\psi = e^{ip_0 x/\hbar} \tag{6.11}$$

It is particle momentum $\hat{p} = -i\hbar \frac{\partial}{\partial x}$ eigenstate, and its eigenvalue is p_0, ($\hat{p}\psi = p_0\psi$). At this time, the particle possesses deter-

mined momentum value P_0 , so in quantum mechanics, particle momentum is "physical reality factor" under ψ state. However, because $\hat{x}\psi \neq$constant · ψ, ψ is not eigenstate of non-particle coordinate x , so ψ cannot accurately predict particle coordinate; If one wants to know particle coordinate, he has to measure it. But measurement is an external perturbation motion, and when particle coordinate is measured, the particle will not be in its original quantum state ψ. Therefore, Albert Einstein believed, under this state ψ , x had unpredictable fixed value, and particle coordinate was not "physical reality factor".

In particle coordinate representation, particle location can be determined, but particle momentum cannot be determined at all, so particle momentum is not "physical reality factor". Albert Einstein also discussed more general cases: given two mechanical quantities are not commutated, $[A, B]\neq 0$, A and B cannot generally possess the same eigenstate; Because of uncertainty principle, when one physical quantity is determined, the other physical quantity cannot be determined at all, therefore, A and B cannot be "physical reality factors" simultaneously. The description of quantum mechanics about "physical reality" is not perfect, so quantum mechanics is also not perfect.

On the ground of complete determinism, Albert Einstein's criticism of quantum mechanics is not unreasonable. The issue is that Albert Einstein's definition of "physical reality" was put forward under the background of "complete determinism" (continuous effect mechanism), while in quantum mechanics, microscopic object in atom is described by the wave function which follows the evolutional law of quantum probability, possessing coherence, and uncertainty ("image" is not ignorable) is "the basic reason that statistical relation occurs in "quantum mechanics". [5] Intrinsic incomplete determinism is the important theoretical basis of quantum mechanics. It obviously mixes the difference between two kinds of

mechanics to require that "physical reality" defined by "complete determinism" be applied in the theory of quantum mechanics. Although, in quantum mechanics, location and momentum cannot become "physical reality factor" of Albert Einstein definition simultaneously, it does not mean that there is no corresponding logical relation between "determinism" and "non-determinism". In quantum mechanics curvature interpretation, "intrinsic incomplete determinism" is the joint of its logical connection.

In fact, in quantum measurement, what pre-measured wave function, having coherence, follows is the evolution law of quantum probability, "intrinsic incomplete determinism" is its essential theoretic basis, and "virtual particle, substance wave" is its physical reality (curvature model); what post-measured wave function, having no coherence, follows is the evolutional law of macro classical probability, determinism is its essential basis, and "real particle, virtual wave" is its physical reality (mass-point model). Measurement leads to the result that "particle will no longer possess its original quantum state" through measurement while the property of wave function is also fundamentally changed. The former is of "intrinsic incomplete determinism" and the latter of determinism. Both transform through measurement.

Take two-slit experiment for example, we introduce continuous effect between instrument and tested system in measurement. Owing to self-entanglement, wave function automatically becomes decoherent and gets to ψ_A, ψ_B, but ψ_A, ψ_B is no longer pre-measured $|A\rangle$ and $|B\rangle$, what it follows is the evolutional law of macro classical probability, it shows no coherence (mixed state), and is of determinism. When shape is neglected and mixed state is transferred to classical state, location and momentum are both "physical reality factors", and agree with the requirement of Einstein "physical reality". While before measurement, $|A\rangle$ and $|B\rangle$ reveal catastrophe, follow the evolution law of quantum probability, and

show coherent property (pure state). It does not do to say "non-determinism" is granted by God, which is an unreasonable excuse or a make-do. We must investigate how non-determinism stems from determinism. "Non-determinism" came into being owing to the fact that discontinuous effect and the "image" of microscopic object is not ignorable in microscopic world. "Physical reality" in quantum mechanics is different from "physical reality" in macro classical mechanics, the former is made up of the "image" constructed by matter wave wavelength (curvature) and "virtual particle", and is the unity of wave particle duality. The change of physical reality is bound to bring about the change of the essence of physical reality factor corresponding to it. Uncertainty is granted by theory when "image" is not ignorable in the measurement of microscopic object and when mass point is abstracted, and not granted by God. Thus, Albert Einstein's issue that "God does not play dice" is solved automatically. Therefore, we call "non-determinism" in quantum mechanics as "intrinsic incomplete determinism".

Quantum mechanics is the basic theory in the description of microscopic world. Although some of its basic concepts conflict with macro experience, these conflicts are between levels of the theories, cognitive and intercommunicative. Background annotation of the reality theory of uncertainty principle will solve these problems.

The second part of EPR paradox demonstrates that the theory of quantum mechanics is not compatible, which specifically expresses that the description of wave function is incompatible in quantum mechanics. [6]

Einstein devised the system composed with particles① and ②, which interacted within the time t (0, T), while after $t>T$, particle ① moved away from particle ② and there was no more interaction, given when $t=0$, quantum states of particle ①+② are known, with the help of Schrödinger equation, any time after that could be predicted, especially the quantum state when $t>T$. Given

quantum state of the two particle system expressed with $\psi(x_1, x_2)$, x_1 and x_2 respectively represent the whole coordinate of the two particles. After $t > T$, measure mechanical quantity $\hat{A}\hat{B}$ separately ($[\hat{A}, \hat{B}] \neq 0$):

①Measuring mechanical quantity $\hat{A}$ of particle ①.

Given $\hat{A}u_n(x_1) = a_n u_n(x_1)$, a_n and $u_n(x_1)$ are eigenvalue and eigenstate of $\hat{A}$, $n = 1, 2, 3\cdots\cdots$ and spreading $\psi(x_1, x_2)$ according to eigenstate $u_n(x_1)$ of $\hat{A}$, we get:

$$\psi(x_1, x_2) = \sum_n \psi_n(x_2) u_n(x_1) \tag{6.12}$$

In equation (6.12), $\psi_n(x_2)$ is the coefficient of $\psi(x_1, x_2)$ spread according to eigenstate $u_n(x_1)$ of $\hat{A}$. $\psi_n(x_2)$, $u_n(x_1)$ with discontinuous numbering property, constructs pure quantum state.

Wave function in equation (6.12) agrees with the evolutional law of quantum probability, showing coherence. In quantum measurement, if the measurement result is a_k, according to the opinion of orthodox quantum mechanics, measurement will induce collapse of wave packet to

$$\psi(x_1, x_2) \xrightarrow{\text{measurement}} \psi_k(x_2) u_k(x_1) \tag{6.13}$$

Wave function after measurement is mixed state, which accords with the evolution law of macro classical probability, showing no coherence. The interference of measurement—macro instrument continuous effect causes the wave function property constructed by $\psi_n(x_2)$, $u_n(x_1)$, $\psi_k(x_2)$ to change from pure quantum state to mixed state.

②Mechanics quantity $\hat{B}$ in measurement of particle ①.

Given $\hat{B}V_s(x_1) = b_s V_s(x_1)$, b_s and $V_s(x_1)$ are eigenvalue and eigenstate of $\hat{B}$ separately, $S = 1, 2, 3\cdots\cdots$ to expand $\psi(x_1, x_2)$ according to eigenstate $V_s(x_1)$ of $\hat{B}$, and we will get:

$$\psi(x_1, x_2) = \sum_s \psi_s(x_2) V_s(x_1) \tag{6.14}$$

In the equation, $\psi_s(x_2)$ is the expanded coefficient of $\psi(x_1, x_2)$ ac-

cording to eigenstate $V_s(x_1)$ of $\hat{B}$, $\psi_s(x_2)$ and $V_s(x_1)$ have the properties of discontinuous numbering and also construct pure quantum state.

Wave function in equation (6.14) accords with the evolutional law of quantum probability, showing coherence. Conducting quantum measurement, and if the measured result is b_k, the measurement will cause collapse of wave packet to

$$\psi(x_1, x_2) \xrightarrow{\text{measurement}} \psi_r(x_2)V_r(x_1) \qquad (6.15)$$

In the same manner, wave function after measurement is also mixed state, and accords with the evolution law of macro classical probability, showing no coherence. The interference of measurement——macro instrument continuous effect causes the properties of wave function constructed by $\psi_s(x_2)$, $V_s(x_1)$ and $\psi_r(x_2)$ to change from pure quantum state to mixed state.

The above Copenhagen interpretation of quantum measure ment puzzled Albert Einstein, who believed that, after t>, particles ① and ② were parted and had no more interaction, so any measurement of particle ① would not affect quantum state of particle ②. That is, since particles ① and ② were parted without any interaction in between, how would particle ② become collapse (that is, particle ② is also measured) when measuring particle ①? Could it be said that between ① and ② exists any information that is conveyed by super velocity of light? Besides, orthodox quantum mechanics is also in an awkward situation that, after measurement, particle ② may be in two different states of $\psi_k(x_2)$ or $\psi_r(x_2)$. Is it possible?

As a result, Albert Einstein believed that, quantum mechanics is not compatible.

David Bohm simplified Albert Einstein EPR paradox and put forward two-particle system in spin singlet state of $\frac{1}{2}$ rotation. After $t \geqslant T$, there was no interaction between the two particles, and there should be not any effects on the spin of particle B when meas-

uring the spin of particle A. David Bohm's presentation of EPR was simpler than Albert Einstein's original words. Therefore, in the following argument of EPR paradox, it is mostly taken as the object of discussion.

The understanding of EPR Paradox factually involves the comprehension of entangled state of quantum mechanics. According to the definition of entangled state, it is linear superposition of direct product of two-particle system eigenstate. In mathematics, two-particle "state" forms the entirety through the interrelation of superposition of direct product. According to orthodox quantum mechanics interpretation, wave function is probability wave, so its entanglement is probability entanglement. In quantum mechanics curvature interpretation, wave function is curvature wave, describing the law of change of microscopic object "image", thus its entanglement is "image" entanglement, and more essentially "curvature" entanglement, or space entanglement. [7] Two particles, whether parted or not, are maintained as a whole by space entanglement. Two-particle entanglement Albert Einstein emphasized is the interactive entanglement between the two particles. Can a pure quantum state be constructed by the interaction plan as Albert Einstein imagined? According to the qualitative analysis in chapter 4, the answer is no.

In David Bohm's spin quantum state, spin up $|\uparrow\rangle$ and spin down $|\downarrow\rangle$ can cause catastrophe. In our understanding, measurement of spin of particle A is the interference of continuous effect; in particle A, spin up $|\uparrow\rangle_A$ and its spin down $|\downarrow\rangle_A$ are interconnected, and its spin state changes from catastrophe to continuity, coherence is declined and returns to the macro classical world. And in particle B, spin up $|\uparrow\rangle_B$, in constructing entangled state of particles A and B, has interconnected with spin down $|\downarrow\rangle_A$ of particle A ($|\downarrow\rangle_A |\uparrow\rangle_B$) through direct product. Therefore, measurement of particle A is bound to influence particle B, through space entan-

glement. Spin state of particle B returns to macro classical world through its connection with direct product of particle A. Owing to the space attribute of wave function, connection between A and B is completely space connection but not interactive connection. It is a connection of non-energy information and may surpass light velocity.

Besides, in left and right rotation of macro movement, catastrophe can only be that of concept. If mechanical analysis is made, between the changes of the two states there must be continuous effect mechanism. Therefore, spin quantum state is not equal to macro left and right rotation states, and practical physical function cannot be mixed with that of concept. Quantum measurement cannot be left out in the change from micro to macro, neither the change of interactive mechanism. We cannot take advantage of mathematics to link different things of different properties together. If so, we will confuse ourselves. The crux in our entanglement of multi-particle quantum state in the past is owing to our neglecting of the difference between macro and micro mechanisms and their relation with quantum state. [8]

Obviously, two-particle entanglement is "image" entanglement. In quantum measurement, the transmission of super-light information is that of non-energy information. In designing quantum computer, the conversion of micro discontinuous effect mechanism to macro continuous effect mechanism must be considered, that is, a quantum measurement mechanism is to be designed to let quantum probability convert to macro classical probability. And it should be considered that information is lost or not. Anyhow, quantum numbering will be realized.

The analysis of EPR demonstration and Schrödinger's cat will directly help us understand the essence of the issue of instrument interference in quantum measurement. So-called instrument interference is the interference of continuous effect between microscopic object and instrument; when the system converted from micro

mechanism to macro mechanism irreversible measurement process occurs. Obviously, when interactive mechanism changes from micro discontinuity to macro continuity, "scattered" image of microscopic object produces "self-entanglement", changing from "non-locality" to "locality"; when "local image" can be ignored in discussion, our description of object state also changes from the description of its space-time "image" to its space-time macroscopic mass point track or mass point probability distribution.[9] Objective "state" contracts from micro variable "image" to macroscopic mass point is a transitional process from discontinuous effect to continuous effect.

6.3 Reconsideration of Quantum Decoherence Interpretation

The famous physicist, John Bell, pointed out, in the theory of quantum measurement, the disappearance of quantum coherence is the cornerstone of philosophical discussion. [10] The conventional interpretation of Copenhagen School believed, complementary principle and uncertainty principle was an important cause that led to the quantum decoherence of tested system (S). However, people would ask: Is this the only and direct cause of decoherence phenomenon? Von Neumann measurement theory revealed the universal features of quantum theory, but finally collapse of wave packet had to resort to God or the human cognition, which is even more difficult to understand. Some physicists who were unsatisfied with subjective interpretation of the issue of "collapse of wave packet" tried to find other ways to the solution. David Bohm, H. Everett, etc successively put forward the theory of hidden variable and multi-world interpretation. Up to 1980s and 1990s, the researches of some physicists including W. H. Zurek indicated: the dissolution of macro object coherence was the result of environment indu-

cing decoherence.[11] Their researches by W. H. Zurek and others finally brought about the interpretation of quantum measurement decoherence.

6.3.1 Basic Mentality of Quantum Decoherence Interpretation

Basic mentality of quantum decoherence interpretation can be summed up as follows:

6.3.1.1 Macro object possesses quantum coherence.

As a universally applied theory, quantum mechanics can describe macroscopic object and even the universe. Macro object and the universe can be written as pure wave function that satisfies evolutional law of Erwin Schrodinger eqeuation. Therefore, macro objects also possess quantum coherence.

6.3.1.2 External and internal environments may induce macro object decoherence.

Owing to the effects of external and internal environments, macro object may quickly (or instantly) reduce its coherence. As a matter of fact, in real life, we cannot see the coherent superposition. External environment may be molecule, atom, etc. in the air or photon in radiation, and may even include background radiation of universal micro-wave. Effects of internal environment are great internal degree of freedom of irregular movement of macro object. Macro object can either entangle with external environment or with internal environment, which lead to the disappearance of coherence.

6.3.1.3 There would be no decoherence if there were no internal dissipation system.

Energy dissipation occurs when macro object couples with environment. Generally, where there is dissipation there occurs decoherence; and without internal dissipation system there is no decoherence effect. If there were no coupling or weak-coupling between

macro object and its environment (external or internal degree of freedom), there would be no dissipative effect, and systematic quantum interference would remain, and this can be used to illustrate superconductivity and superfluid, which may keep macro quantum superposition state although they have much internal degree of freedom.

In short, fluctuation of Brown movement model and dissipation are the sources that lead to decoherence, especially the effect of the former.

6.3.2 Application of Decoherence Interpretation of Specific Model in Quantum Measurement

Correlation between instrument (M) and tested system(S)

Von Neumann measurement theory points out, quantum measurement operation "reads out" the state of tested system (S) from instrument (M) state.[12] This process of "reading" described by quantum mechanics must have the correlation between tested system (S) and measurement instrument (M). If $|\psi\rangle=\sum_n c_n|n\rangle$ is the initial state of tested system (S), while $|e\rangle$ is the initial state of instrument (M), from the wave function of the total system (S+M) formed through system (S) plus instrument (M) (factorized initial state), quantum entanglement can be described by:

$$|\psi_{\text{总}}(0)\rangle=\sum_n c_n|n\rangle|e\rangle \tag{6.16}$$

Based on decoherence theory, quantum entanglement tells us that, un-factorized final state is:

$$|\psi(t)\rangle=\sum C_n(t)|n\rangle|e_n\rangle$$

$|e_n\rangle$ is the final state of instrument, $n=1,2,3\cdots\cdots k$

Once instrument (M) is found to be on $|e_k\rangle$ in measurement, we will know that the total system (S+M) is on component $|k\rangle|e_k\rangle$, that is, the whole wave function "collapses" to $|k\rangle|e_k\rangle$,

and it is determined that tested system (S) is on $|k\rangle$.

Note: in equation (6.16), wave function of system (S) and instrument (M) are both pure quantum state. According to the basic way of thinking of decoherence interpretation, the above operation of quantum measurement can be simplified to the following:

System (S) and instrument (M) are both in pure quantum state ($|n\rangle$, $|e\rangle$)→ construct quantum entangled state $|\psi(0)\rangle$ between system (S) and instrument (M)→initial state of macro instrument (M) $|e\rangle$ automatically decoheres to $|e_n\rangle$→ find instrument (M) on $|e_k\rangle$ state→tested system(S) then decoheres to $|k\rangle$ state (mixed state).

That is the application of decoherence interpretation to the above particular model in quantum measurement. As an applied model, the way of thinking of equation (6.16) is distinct, but its logic is not compatible, and the difficulty of "wave packet collapse" still exists.

First, since macro object, including instrument (M) may quickly or instantly decoheres, once an instrument (M) is "born", it will quickly or instantly evolves from "pure state" to "mixed state", and this evolution is not reversible.

Second, when measuring quantum system (S) with instrument (M), for the previous reason, instrument (M) has been decohered into mixed state before measurement. Therefore, in any practical measurement, instrument (M) is impossible to exist in "pure state". When we say M and S interact, it is only a fond dream that M can be in an ideal state (pure state). Ideal state of equation (6.16) has only the significance in mathematical operation but no practical physical significance.

Third, to give equation (6.16) practical physical sense, macro instrument (M) cannot become decoherent before it couples with tested system(S). We must be resolved to let "instrument cat" wait there neither alive nor dead, which will violate the interpreta-

tion of the basic theory that macro object quickly or instantly becomes decoherent; or macro instrument (M) quickly or instantly becomes decoherent, but it will violate experiment practice and the principle of quantum measurement that pure state→mixed state is irreversible if it is instantly reduced to pure quantum state before coupling with tested system (S) and then automatically return to mixed state with tested system becoming decoherent according to the basic thinking of decoherence interpretation.

Fourth, when instrument (M) is known to be in $|e_k\rangle$ state, the whole wave function (S+M) collapses to $|k\rangle|e_k\rangle$ state, and system (S) can be ascertained to be in $|k\rangle$ state. Since the logic of equation (6.16) is not compatible, and instrument M has become decoherent before measurement, the time needed for macro instrument (M) to become decoherent has no contribution to "wave package collapse" of tested system (S), so the puzzle of "wave package collapse" is not cleared up.

Based on the above four causes, we believe that decoherence operation described by equation (6.16) is only mathematical operation constructed "for practical purposes", and that it does not represent any practical physical process and has no physical sense. The most knotty problem of "wave package collapse" still remains in its pattern.

The analysis of auto-decoherence of macro cat also falls into the same fate. In Schrödinger's cat cage, "cat", as "instrument (M)" that drives decay atom to become coherent, does not have any better fate in the present auto-decoherence operation model. The pitiful cat had to wait in an awkward position, neither dead nor alive (once atom decay system (S) is put into the cage, it begins to become decoherent and brings atom back to macro world), or to return to the neither dead nor alive state after auto-decoherence, the instance decay atom is put into the cage, and then guide decay atom to become coherent. The both conditions violate the

basic principle of quantum mechanics.

Logically, existing operation models of quantum decoherence interpretation cannot compatibly explain the problems of quantum measurement.

6.3.3 New Consideration of Auto-decoherence Interpretation of Quantum Entanglement

Basic ways of thinking of the new consideration are:

① Von Neumann assumed that: "Pure quantum state" of macro object has only symbolic sense in decoherence theory, for once macro object is "born", it will instantly decohere and becomes mixed state. Any practical measurement instrument (M) can only appear in the form of mixed state in quantum measurement.

② The essence of quantum measurement is that macro instrument (M) provides a continuous effect mechanics for tested system (S) and eliminates catastrophe between eigenstates, and then, coherence disappears and pure state is changed into mixed state.

③ What the instrument (M) of the mixed state distinguishes is tested system (S) of mixed state, and this is random distinction.

④ Tested system (S) decoherence and the transition of pure state to mixed state embody the structural transition of physical reality described by theory in micro quantum world and macro classical world.

Take two-energy-level micro particle as an example, we construct decoherence model as follows:

If $|A\rangle$ and $|B\rangle$ are branches of two-energy-level pure quantum state of micro particle, ψ_A, ψ_B are branches of corresponding mixed state after measurement. We believe that, in measurement, $|A\rangle$ may transform to ψ_A and $|B\rangle$ may transform to ψ_B, which is a real physical process. Therefore, association is established between $|A\rangle$ and ψ_A, $|B\rangle$ and ψ_B quantum. Quantum measurement only provides a continuous environment variation from state to

state in catastrophe for tested system (S). And decoherence of tested system(S) is the product of self-state entanglement of system before and after measurement. According to the above ways of thinking, self-entangled state is:

$$\psi=\psi_A \otimes |A> + \psi_B \otimes |B> \qquad (6.17)$$

Equation (6.17) is similar to associating the space state ψ_B and ψ_c describing which path atom take through Rabi revolving and atomic interior state $|2>$ and $|3>$ to form "the so-called entangled state".

$$\psi_T=\psi_B \otimes |2> + \psi_C \otimes |3>$$

Thus, it is discovered that, under the condition that atom momentum does not change, interference stripe between ψ_B andψ_C disappears after inner state marks are made as above for atom space motion. "[13]

In equation (6.17), state $|A>$ and $|B>$ before measurement is regarded as an inner state (pure quantum state) of microscopic object, while ψ_A and ψ_B are mixed state after measurement; continuous effect of instrument M on system S is regarded as inner dynamics in the transition of $|A> \rightarrow \psi_A$ and $|B> \rightarrow \psi_B$. However, this inner dynamics has changed the catastrophic nature of wave function in original pure state and realized the transition of pure state to mixed state in self-entangled state.

The above model can be applied to the analyses of two-slit experiment and Schrödinger's cat. Two-slit provides two energy level branch of electron's wave function. Electron's wave function $|A>$ and $|B>$ before measurement is pure quantum state, which can be regarded as electron's inner state (two-slit interval is similar to the production of a mutant area); while states ψ_A and ψ_B after measurement are electron's mixed state. Electron decoherence can be realized by producing self-entangled state as that in equation (6.17) and by marking inner state. Quantum measurement only provides a transitional power inside system (S) with continuous effect.

As for Schrödinger's cat, we can also let pure state of living ($|A_{alive}>$) and cat ($|A_{dead}>$) respectively transit to mixed state of living (ψ_{alive}) and dead cat (ψ_{dead}), effects of internal and external environments and energy dissipation only provide transformation mechanism of continuous effect from pure state in the system (S) to mixed state. Thus, cat's decoherent self-entangled state can be written as:

$$\psi=\psi_{alive}\otimes|A_{alive}>+\psi_{dead}\otimes|A_{dead}> \tag{6.18}$$

In equation (6.18), $|A_{alive}>$ and $|A_{dead}>$ are cat's pure quantum state (or cat's inner state) before decoherence, ψ and ψ_{dead} are cat's mixed state, and $\otimes$indicates the correlation provided by continuous effect needed for pure state to change to mixed state. In equation (6.18), to seek probability distribution in ψ and to mark internal pure state can realize cat's instant auto- decoherence. [14]

To sum up, quantum measurement theory of curvature interpretation in quantum mechanics[15][16] can be briefly expressed as follows:

① Wave package collapse is not needed.

In measurement, wave package does not exist, and there are only auto-decoherence and self-entanglement of tested system caused by the interference of continuous effect.

② Each branch of wave function exists in parallel and corresponds to macro world.

In microscopic world, as in atom, wave function branches of different energy levels exist in parallel. Between different energy levels, energy is discontinuous, effect is discontinuous and catastrophic, and independent interference wave sources can be constructed. However, eigenfunction branch itself corresponding to each energy level is continuous, single-valued and periodic function. Thus, eigenfunction of each energy level can correspond to macro world. Macro particle information of microscopic object is contained in amplitude (reference curvature) corresponding to its

eigenstate.

③ Quantum measurement is a process to eliminate catastrophe or independent interference wave sources. In self-entanglement and auto-decoherence, global coherent wave disappears and particle of macro "local" form comes into being. The process of "particle taken in by light" and "wave exhibited by particles" that Louis de Broglie dreamed for has finally had its ideal illustration here.

④ Instrument's (M) identification of eigenvalue is random in measurement

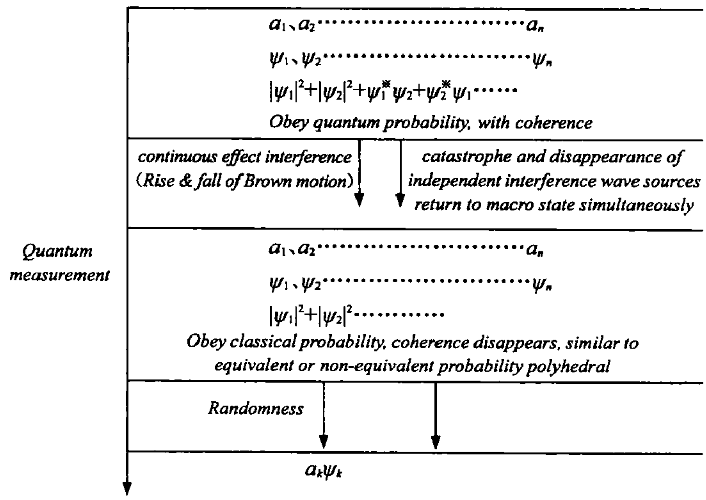
Continuous effect of instrument (M) on tested system (S) forces millions of eigenstates to transform to macro world in self-entanglement, but the eigenvalue of which eigenstate can be caught by instrument (M) is random. Nevertheless, eigenvalue of eigenstate that is near atomic nucleus has more chances to be identified, with higher probability, and vice versa. When eigenvalue of eigenstate at certain energy level is exactly caught by instrument (M), the probability will become 1. It is unknown why this time the eigenvalue of this eigenstate is measured, only statistical law of probability that tells.

⑤ Man and measurement instrument (M) belong to macro world.

Instrument (M) is macro object and can become auto-decoherent when using the effect of internal and external environments, so the motion of instrument (M) is of macro determinism. Man and macro instrument (M) belong to macro objects, and man only has experienced cognition of continuous effect, so man's observation activity is also of determinism. Therefore, man and measurement instrument belong to the same macro world. The readings on the instrument are what man cognizes. Measuring process is: through the interference of continuous effect, force quantum probability to change to macro classical probability so that man can obtain experienced cognition. Curvature interpretation of quantum mechanics does not need multi-dimensional world but macro world and micro

world.

Quantum measurement process is illustrated by the following chart:



Quantum mechanics curvature interpretation may bring about good chance to eliminate the deep-rooted conflicts between theory of relativity and quantum mechanics, the direct results of which are:

① In microscopic sphere, there is no independent and unchangeable electron in atom, the "image" of electron is variable, atomic electron is different from the electron separated from atom, electronic "substance of appearance" changes in or out of atom, and traditional analytical reduction has its limitedness;

② Abstract principle of macroscopic mass point cannot be applied to electron in the depth of atom in the microscopic world;

③ The physical reality described by quantum mechanics is different from mass point in classical mechanics; physical reality in the depth of atom in quantum mechanics is the combination of curvature wave and virtual particle, and the unity of wave particle duality;

④ It is impossible to integrate things of different levels of cognition to the same level of cognition. What we can do is to find out the logic "interface" of different levels of cognition;

⑤ Considering the information loss in quantum measurement, the realization of quantum computer must have a counter process from continuous effect to discontinuous effect.

⑥ There is no energy dissipation between "Frozen stiff" atoms, and macroscopic "pure quantum state" can be established, which can ensure the principle in the research and development of quantum computers. However, how can we guarantee that the human beings will survive in this "frozen stiff" world?

Reference

[1] Zeng Jinyan, et al. New Progress of Quantum Mechanics [M]. Beijing:Beijing University Press, 2000:70.

[2] Zeng Jinyan, et al. New Progress of Quantum Mechanics [M]. Beijing:Beijing University Press, 2000:105.

[3] Zhao Guoqiu. New Ideas for Eliminating Deep-Seated Contradictions in Relativistic Quantum Mechanics // Science Technology and Dialectics, [J]. 2005(1).

[4] Zeng Jinyan, et al. Quantum Mechanics [M]. Beijing: Science Press, 1995:172-173.

[5] M. Jammer. Philosophy of Quantum Mechanics [M]. Translated by Qin Kecheng, Beijing:Commercial Press, 1989:70.

[6] Zeng Jinyan, et al. Quantum Mechanics [M]. Beijing: Science Press, 1995:192-199.

[7] Wu Guolin. Quantum Entanglement And its Philosophical Essence // Studies in Dialectics of Nature [J]. 2005(7).

[8] Zhao Guoqiu. New Ideas to Eliminate Deep-Seated Contradictions in Relativistic Quantum Mechanics // Science Technology and Dialectics [J]. 2005(1).

[9] Zhao Guoqiu, Gui Qiquan. et al. New Divine Comedy of Physics [M]. Wuhan: Wuhan Publishing House, 2004: 2nd edition, 220-222.

[10] J. S. Bell. On Wave Packet Reduction in the Coleman Hepp Model, Helv, Phys, Acta [J]. 1975(1):48,93-98.

[11] Li Hongfang. The Decoherence Interpretation and Philosophy//Journal of Natural Dialectics [J]. 2005(2).

[12] Sun Changpu. Quantum Decoherence Issues//New Progresses of Quantum Mechanics (1) [M]. Beijing University Press, 2000:70.

[13] S. Dure, T. Nonn, and G. Rampe, Nature 395,33(1998).

[14] Zhao Guoqiu, Gui Qiquan. New Divine Comedy of Physics [M]. Wuhan Publishing House, 2004:217-222.

[15] Zhao Guoqiu, Gui Quanqi. Descriptive Target of Schrödinger Equation and Wave-Particle Unity of Curvature Interpretation in Quantum Mechanics//The 13th International Conference for Logics, Methodology and Science & Philosophy, Beijing, 2007(8).

[16] Zhao Guoqiu. Between Physics and Philosophy —Interactive Reality & Curvature Interpretation in Quantum Mechanics. China News United Press, 2005:208—218.

第六章
量子力学曲率解释中的量子测量

第一节　量子力学曲率解释与双缝实验

原子深处，通过物质波波长 λ（曲率半径）为微观客体建构的“形”不能忽略，牛顿力学中的质点抽象原则不适用或不能照搬，无法研究电子的轨道运动。客体运动规律必须由反映客体空间结构的波函数来描述。电子波是曲率波，波是实的，质点是虚的。曲率波的传播就是物质波的传播。从原子中制备出来的电子波，通过双缝时，只有遇到类似原生制备条件时，才能继续表现为波，否则就可能表现出宏观的粒子性。

一、标准哥本哈根解释与双缝干涉实验

按照标准哥本哈根解释，双缝实验中，如果在测量中确定了粒子通过哪一缝，便强调了波粒二象性中的粒子特性，与粒子性互补的波动性就被排斥了，干涉条纹便将消失。具体地讲，由海森伯测不准关系：准确知道粒子通过路径 A（如挡住 B 缝），意味着垂直于 A 的方向上完全确定了粒子的位置。如果位置测量精确到 Δx，则由测不准关系

$$\Delta p_x \cdot \Delta x = \hbar \tag{6.1}$$

知，这个测量将对垂直于路径 A 方向上的动量产生 $\Delta p_x = \dfrac{\hbar}{\Delta x}$ 的扰动，从而干扰到达屏上粒子的位置，改变了波的相位，造成了干涉条纹的消失。

标准哥本哈根解释依据的理论基础是玻尔的互补原理：物质运

动具有粒子和波的双重属性，但在同一实验中二者是相互排斥的。测不准关系是引起被测系统量子退相干的一个重要原因。[1]

哥本哈根学派对双缝干涉实验的解释不能令人满意。主要原因有：

①实验表明，一个粒子自身也可以产生干涉，单个“电子实体”如何通过双缝？难道一个粒子同时可以通过两个缝？

②概率波是数学波，而电子波有真实的物理作用，数学波与物理实在的关系如何处理？

③海森伯认为是一种“潜能”和“趋势”控制量子概率的发生，它像是“电子实在”中间层次的“替身”，而由中间层次的“可能性”向“现实性”转化的力学基础是什么？

④通过双缝的电子波遵从量子概率的演化规律，具有相干性，与此相反，通过双缝的经典粒子遵从经典概率的演化规律，没有相干性。在量子测量中，电子从遵从量子概率转向遵从经典概率，其由波向粒子转化或波包坍缩的物理本质是什么？

⑤产生光、电子衍射和干涉的重要条件是：(a)独立的相干波源；(b)恒定的周相差；(c)缝宽 Δx 与光、电子的波长 λ 可以比拟。如果，缝宽 Δx 比光、电子的波长 λ 大得很多，则衍射和干涉自行消失。此时电子从遵从量子概率转向遵从经典概率，这是否也是一个自动退相干？它和量子测量引起的退相干有何物理机制上的区别？

如此等等。

总之，哥本哈根学派对上述这些问题的回答很难令人满意，或者他们根本就不作物理回答而是试图用哲学原理回避现实中的物理追究。

二、量子力学曲率解释与双缝干涉实验

(一)双缝前电子波的制备

从原子中制备出来的电子，我们已经证明只有在原子深处为电子建构的“形”不可忽略时，才可用波来表示(因为当能级 n 趋向无穷大时电子波动论即变成了经典电子论)。此时背景空间与微观客体不可分离，我们无法研究“点电子”的轨迹运动，只能通过波函数研究“电子”所占空间的形态结构性质及由此引起的“可视度”的变化。量子力学曲率解释中，ψ 是曲率波，描述为电子建构的“形”的变化规

律，dv 是由曲率描述的体积元，V 空间便有了物理意义。若通过双缝的电子波记为 ψ，则 ψ 是实的，“点电子”却是虚的。爱因斯坦把电磁场称为“鬼场”，场是虚的，光子是实的。而进入双缝前的电子波，可认为是刚从原子中制备出来的那个电子波，场是实的，点电子是虚的，可称为“鬼电子”。而且这个实体的波动场，只有遇到类似于原生制备条件（“形”不可忽略和突变特性）时，才能继续表现为波动并具有相干性，否则就可能表现出宏观的粒子性。

（二）双缝对波和粒子的识别

“双缝”是光、电子等微观客体波动性或粒子性的一种识别装置。若缝宽为 Δx，通过双缝的物质波的波长为 λ，则由测不准关系有

$$\Delta p_x \cdot \Delta x = \hbar \tag{6.2}$$

由德布罗意关系有

$$p \cdot \lambda = \hbar \tag{6.3}$$

由于 $\Delta p_x \leqslant p$，则有

$$\Delta x \geqslant \lambda \tag{6.4}$$

(6.4)式表明，双缝实验中缝宽 Δx 比物质波的波长 λ 要大。这就是双缝产生波的干涉的基本条件。

实验表明，$\Delta x \ll \lambda$ 和 $\Delta x \gg \lambda$，单缝衍射和双缝干涉都不能发生。只有 Δx 与 λ 可以比拟，大得不多时波的干涉才能发生。这正是(6.4)式的物理意义。此时，我们可以认为，双缝前用波长 λ 为电子建构的“形”，在双缝中“形”对讨论的问题的影响仍然不能忽略，微观客体与背景空间不能局域分离。从双缝中传出来的依然是电子波，而双缝间的间隔成了二能级分支的突变区，双缝成了干涉波的波源。

如果 $\Delta x \gg \lambda$，缝中“形”的影响可以忽略，根据牛顿力学中的质点抽象原则，则光、电子就表现为点粒子；如果 $\Delta x \ll \lambda$，则光、电子就以粒子的形式反弹。这正是实验的结论。

可见，玻尔所说“设计了一个产生波或粒子的仪器系统”，关键在于为微观客体建构的“形”，在具体环境中能否被忽略。

当 $\Delta x \geqslant \lambda$ 时，缝中波动有实体属性，而粒子是虚的，是实体电子的“幽灵”，“鬼”电子通过哪一缝无关紧要。一个电子同时通过双缝的矛盾也随之得到了解决。

（三）双缝后波的干涉和退相干

量子力学曲率解释中，我们为微观客体建构的“形”的大小与在

"形"内找到"虚点粒子"的概率成反比，而概率与构成"形"的曲面的曲率成正比，双缝后的波函数 ψ_1、ψ_2 具有双重属性，既是曲率波又有概率属性。显示屏上点粒子落点的概率由波函数的概率属性决定；虚点粒子向实点粒子的转换由波函数的空间属性决定。量子测量中，仪器与被测系统的相互作用——宏观连续作用的介入，是"离散波动形态"向"局域粒子形态"转换的重要条件。显然，这个转换有一定的过程，不可能突变。如果介入的作用是非连续作用，前后态就可以突变，构成新的叠加态，形成新的干涉项。但实验看到的不是新的干涉而是干涉的消失。是仪器宏观连续作用的介入，促成了波函数的"自我纠缠"，形成"自纠缠态"。波函数的"自身纠缠"就是"形"的自我纠缠，体现在相互作用中测量前的突变波函数如何转换成测量后的连续波函数。这个过程就是退相干过程。在新的环境中，若"形"可以忽略，"虚质点"就有了"实体性"的归属。没有量子测量作用，没有"形"的"自纠缠"，粒子就无法恢复"宏观原形"。因此，双缝后对波函数的测量——连续作用的介入，是波向粒子转换的重要物理条件。

一个粒子通过双缝并在屏上显示落点的事实，是粒子"自相干"、"自纠缠"、"自动退相干"的产物。

总之，原子深处微观客体与其所在环境的背景空间不可分离，客体必须由反映空间结构的波函数来描述。波是实的，质点是虚的。能级间的突变性，是形成独立相干波源，造成相干性的根本原因。我们不能用统一不变的思维方式处理不同认识层次的自然现象，试图用一种思维方式统一世界物质图景的努力是徒劳无益的。量子力学与相对论描述的是不同认识层次的问题。它们可以相互沟通，找到相互的逻辑连接，但不能替代。量子力学曲率解释对双缝实验的解释，是既不违背爱因斯坦的实在论要求，也不违背玻尔基本思想的一种较好解释。量子力学曲率解释在量子力学与相对论之间找到了一个好的逻辑接口。

第二节 薛定谔猫与 EPR 理想实验

量子态的纠缠，概率解释中是概率的纠缠，或者叫概率幅的纠

缠；曲率解释中包含有微观客体“空间形态”的纠缠；由爱因斯坦的“相互作用”带来的纠缠，只是提供一个宏、微观的转换机制。认清微观作用机制与宏观作用机制的本质区别之后，量子力学曲率解释为消除薛定谔猫和 EPR 悖论提供了新的认识进路，并可作出较为详细的定量分析。

一、Schrödinger 猫悖论

(一)Schrödinger 猫悖论的起源

人们希望量子力学是关于整个宇宙的普适理论，它既能描述微观物理系统，还能描述观察这个系统的宏观测量仪器。希望仪器和被测系统一样，都遵从量子概率的演化规律。Von Neumann 和威格纳最先提出了试图包含仪器和被测系统的量子测量理论。在Von Neumann 的理论中，通过系统和仪器的相互作用，系统和仪器被看成一个服从量子力学演化规律的整体，当把整体约化到被测系统部分，人们就可看到量子退相干或波包坍缩现象。

Von Neumann 理论有一个重要缺陷。人们发现，由于他没有充分考虑仪器的宏观属性，要想实现波包坍缩，必须引入一连串无穷的仪器链，最终还得借系统之外的观察者，上帝或人的思维，它使得最后一台仪器产生波包坍缩，从而依次实现量子退相干。

冯·诺依曼的思路方法是：假定宏观仪器与微观被测系统之间的相互作用，只改变仪器的状态。我们从仪器的状态可以“读出”系统的状态。

最早质疑上述测量理论的人是 Schrödinger。1935 年，Schrödinger 提出了一个假想实验，设想：一密封笼子内关着一只可怜的猫，同时放置一个盛有毒药的瓶子，瓶的好损由一个原子放射性装置控制。一小时内原子衰变和没有衰变的概率相等。如果原子处于激发态 $|\uparrow\rangle$，瓶子完好无损，猫未受到毒害，是活的，如果原子跃迁到基态 $|\downarrow\rangle$，伴随光子的释放，启动打破瓶子的小锤，瓶子破损，毒药释放，猫被毒死。

根据量子力学对波函数的解释，$|\uparrow\rangle$、$|\downarrow\rangle$ 都是概率波，反映电子在能级上跃迁概率。由叠加态原理，原子可处在 $|\uparrow\rangle$ 和 $|\downarrow\rangle$ 的叠加态

$$
\begin{aligned}
&|\psi_{原子}\rangle=\alpha|\uparrow\rangle+\beta|\downarrow\rangle \\
&|\alpha|^2+|\beta|^2=1
\end{aligned}
\tag{6.5}
$$

(6.5)式表明原子可处在一个既释放光子，又不释放光子的可能状态上。如果原子就是 Schrödinger 所指的猫，“原子猫”可处在“不死不活”的状态。

由于人们认为量子力学是普遍适用的，宏观的猫态亦可用量子力学的波函数描述，并且猫态同样具有量子概率的演化规律——即具有相干性。若$|活\rangle$和$|死\rangle$是猫的两种能量本征态，则

$$|\psi_{猫}\rangle=\alpha|活\rangle+\beta|死\rangle \tag{6.6}$$

对于宏观的“猫”加微观的“原子”这个复合体系“猫＋原子”$|\psi_{复合}\rangle$则有

$$|\psi_{复合}\rangle=\alpha|活猫\rangle|\uparrow\rangle+\beta|死猫\rangle|\downarrow\rangle \tag{6.7}$$

(6.7)式表明，在“原子加猫”的笼子中，猫确实可以处在不死不活的状态。

根据量子测量的哥本哈根解释，笼中猫的生死不依赖于开箱前的“客观存在”，而是决定于开箱后的“观察”。在开箱的一瞬间，人能够让“不死不活”的猫坍缩到真实的“死”或“活”的状态上(其本质是“观察”——人的思维作用，实现了量子概率向宏观经典概率转化)。人的意识决定了猫的生与死，这显然是不合理的。这就是 Schrödinger 猫悖论的起源。

(二)宏观物体的退相干

孙昌璞从宏观物体退相干的视角讨论了上述悖论。孙昌璞认为：“我们谈到的宏观的猫的死和活，只是代表两种集体状态，而人们说的‘宏观的猫’，意味着猫由许多微观粒子组成。因而 Schrödinger 猫态完整的描述必须包含无穷多内部微观自由度，不能粗略地简化为

$$|\psi\rangle=\alpha|活\rangle+\beta|死\rangle \tag{6.8}$$

其正确的形式应包含对应于死活的内部状态$|D_j\rangle$、$|L_j\rangle$($j=1,2,3\cdots\cdots N$)，即

$$|\psi\rangle=\alpha|活\rangle\otimes\prod_{j=1}^{N}|L_j\rangle+\beta|死\rangle\otimes\prod_{j=1}^{N}|D_j\rangle \tag{6.9}$$

这时，如果谈论猫的死与活而不管其内部如何，就应使用猫的约化密

度矩阵

$$
\begin{aligned}
P &= \mathrm{tr}_{内} |\psi><\psi| \\
&= |\alpha|^2 |活><活| + |\beta|^2 |死><死| \\
&\quad + (\alpha^{*}\beta |死><活| \prod_{j=1}^{N} < L_j \mid D_j > + h \cdot e)
\end{aligned}
\tag{6.10}
$$

因为对任一归一化的态$|<L_j|D_j>|\leqslant 1$，当$N\to\infty$时，退相干因子$F(N,t)=\prod_{j=1}^{N}<L_j \mid D_j>$，将有可能趋于0。宏观Schrödinger猫的相干叠加在极短时间的演化也会失去相干性。”[2]

不难看出，孙昌璞改写猫的波函数的目的：(6.8)式到(6.9)的转变，实际上是在为猫的“纯量子态$\xrightarrow{到}$混合态$\xrightarrow{到}$经典概率态”的转变创造条件。孙教授将量子概率向宏观经典概率的转化放在猫身上，而其触发条件则是“当$N\to\infty$时，退相干因子$F(N,t)\to 0$；或很多内部态分量中之一，$|L_j>$和$|D_j>$变成正交，内积等于0”。这虽然消除了客观唯心主义(上帝)，但却是，一方面为相干性留有余地(无穷的振荡过程的存在)，另一方面又加进了一个人为的约定：$|L_j>$和$|D_j>$变成正交。

实际上，在Schrödinger猫悖论中，锤的状态变化，瓶的状态变化亦不能等同原子衰变状态的变化，宏观的锤和瓶亦不存在$|动>+|不动>$、$|破>+|不破>$突变的叠加量子态。宏观的锤和瓶及毒药仍然需要一个退相干过程，否则，宏观真实作用就无法实现。这仍然需要构造孙教授的“宏观集体态和内部态的纠缠”，否则，量子概率就无法过渡到宏观经典概率。毒药的状态(纯量子态)就不能回复到宏观的真实作用状态。这样，猫即使不顾“集体主义精神”，按孙教授的思路独自退相干回到现实世界，也无济于事。何况构造锤和瓶“宏观集体态和内部态的纠缠”，按孙教授的思路自动退相干，恐怕比“猫”还要难。

(三)量子力学曲率解释中的Schrödinger猫

其实，Schrödinger猫悖论的出现并不在于人们忽视了猫的“无穷多内部微观自由度”，而在于混淆了微观非连续作用和宏观连续作用，微观量子概率和宏观经典概率的根本区别。在于将微观符合量子概率演化规律的波函数，不加区分地应用于宏观客体。尽管量子

力学认为，量子理论对宏观乃至宇观都普遍适用，但当与人类的宏观经验层次相联系时，我们就不能毫不顾及量子现象对于宏观经验产生的逻辑基础的适用性。不能不顾及量子现象与宏观现象的本质区别。如果用掷骰子相比，微观的骰子既可以掷出"1"点或者"2"点的状态，还可以掷出"1"+"2"点同时存在的状态及附加的相干项，而宏观的骰子则只能掷出"1"点或者"2"点的状态而没有相干项。

仔细分析，Schrödinger 猫理想实验，实际上是由两部分不同性质的构件组成。一部分是衰变的原子，符合量子概率的演化规律($\hbar\neq 0$)，具有相干性；另一部分是锤子、玻璃瓶、毒药、猫等宏观组件，它符合宏观经典概率的演化规律($\hbar=0$)，没有相干性。

在原子世界，能量的接收和失放是一份一份的，不连续的，因而相互作用在能级之间的体现是不连续的。能级间的突变性，为独立的相干波源，波函数的正交性和线性叠加特征提供了物理基础。处在微观世界的原子，其波函数符合量子概率的演化规律，具有相干性，既衰变又不衰变的叠加态$|\psi_{原子}\rangle=\alpha|\uparrow\rangle+\beta|\downarrow\rangle$是方程的解。

在宏观世界，如实验中的锤子、瓶子、猫等，能量的变化均是连续的，没有能级跃迁的概念，相互作用在能级之间的体现是连续的。锤的"动"与"不动"，玻璃瓶的"好"与"破"，猫的"死"与"活"都不存在突变。自身的连续作用，亦或环境的影响，独立的相干波源消失，也使宏观客体在自纠缠中能自动退相干，自动完成量子测量，实现量子概率向宏观概率的转化。这就是宏观物体的退相干机制。

可见，宏观的锤、瓶、猫均可简化为宏观质点的运动。位置和动量可以对易，具有相同的本征函数。它们的运动均是决定论的，遵从宏观经典概率的演化规律，没有波的干涉效应。$|动\rangle+|不动\rangle$、$|好\rangle+|破\rangle$、$|死\rangle+|活\rangle$突变的叠加态不存在。[3]

由此，我们认为 Schrödinger 猫悖论之所以产生，其根源在于：

1. 误认为"原子猫"与"宏观猫"具有完全相同的量子概率属性。实际上，由于宏观连续作用的自动引入，自纠缠就能使"宏观猫""自动"退相干。宏观客体相干性的自行消失，使"宏观猫"最终只遵从宏观经典概率的演化规律。"宏观猫"没有$|死\rangle+|活\rangle$突变叠加态。

2. 由于忽视了原因 1，基于 Von Neumann 假设，Schrödinger 把原子衰变、锤的运动、瓶的好破、猫的死活都纳入量子概率的演化范畴，

关猫的笼子里成了一锅“量子汤”。“开箱动作”作为“量子概率”向“宏观经典概率”的转化条件，是量子测量的错位。

3. 要想 Schrödinger 猫悖论不复存在，办法就是将“开箱动作”放在衰变原子上，让原子退相干，使量子概率向宏观经典概率的转化，即量子测量在这里进行。电子波和光波失去了相干性，变成了实体的电子和光子，加上宏观的猫在自纠缠中自动退相干，这就化解了 Von · Neumann 假设危机。在上述 Schrödinger 猫笼中，锤的运动、瓶的好损、猫的死活都将遵从宏观经典概率的演化规律，是决定论的，与宏观经典概率不相悖。打开笼盖，不管你看还是不看，猫要么死了，要么还活着。

这就是量子力学曲率解释对 Schrödinger 猫悖论的详细分析。

二、EPR 佯谬

1935 年，Einstein，B. Podolsky 和 N. Rosen 共同发表了一篇短文，对正统量子力学基本原理和概念的诠释提出了批评。此文提出的问题简称 EPR 佯谬。EPR 一文有两点结论：

①量子力学对于“物理实在”的描述是不完备的。爱因斯坦反对的是“测不准原理”，认为“上帝不会掷骰子”。爱因斯坦坚持的是决定论。

②量子力学理论是不自洽的。这实际上涉及到多粒子体系纠缠态，在量子力学中就表现为“非定域性”。爱因斯坦坚持“定域性”，即不可能有超光速信息传播存在。

关于“物理实在”爱因斯坦定义如下：

“如果在对系统没有任何干扰的情况下，我们能够确定地预言一个物理量的值，那么，这个物理量对应于物理实在的一个要素。”物理理论所描述的对象是“物理实在”，在牛顿力学中这个物理实在就是“质点”。物理实在有各种要素决定，能量、动量、位置和时间就是决定物理实在的要素。爱因斯坦要求物理理论中的“物理量”与“物理实在的要素”必须一一对应，而且有确定的值，否则理论就是不完备的。[4]

根据上述定义，爱因斯坦考虑到一个一维粒子的量子态：

$$\psi = e^{ip_0x/\hbar} \tag{6.11}$$

它是粒子动量 $\hat{p}=-i\hbar\frac{\partial}{\partial x}$ 的本征态，本征值为 p_0，($\hat{p}\psi=p_0\psi$)，此时，粒子具有确定的动量值 P_0，所以，量子力学中粒子的动量在 ψ 态下是“物理实在的要素”。但由于 $\hat{x}\psi\neq$常数・ψ，ψ 并非粒子坐标 x 的本征态，ψ 不能确切预言粒子的坐标，而要想知道粒子的坐标，只能靠测量。但测量是一种外来的扰动，而且测量粒子的坐标后，粒子将不再处于原来的量子态 ψ。因此，爱因斯坦认为，在此 ψ 态下，x 有不可预言的确定值，粒子的坐标不是“物理实在的要素”。

在粒子的坐标表象中，粒子的位置可以确定，但粒子的动量又完全不能确定，因此粒子的动量又不是“物理实在的要素”。爱因斯坦还讨论了更一般的情况，设两个力学量不对易，$[A、B]\neq 0$，则 A 和 B 一般不能具有共同的本征态，由于测不准关系，一个物理量确定了，另一个物理量就完全不能确定，因而，A 和 B 不能同时是“物理实在的要素”。量子力学对“物理实在”的描述是不完备的，因此量子力学也就是不完备的。

站在完全决定论的立场上，爱因斯坦对量子力学的批评不无道理。问题是爱因斯坦“物理实在”的定义是以“完全决定论”(连续作用机制)为背景提出来的，而量子力学中，原子中微观客体由遵从量子概率演化规律的波函数来描述，它具有相干性，不确定性(“形”不能忽略)是“量子力学中出现统计关系的根本原因”[5]，内禀非完全决定论是量子力学的重要理论基础。要求以“完全决定论”定义的“物理实在”，在量子力学理论中也适用，显然混淆了两种作用机制的区别。但量子力学中位置和动量不能同时成为爱因斯坦定义的“物理实在的要素”，并不等于“决定论”与“非决定论”之间找不到相应的逻辑联系。量子力学曲率解释中，“内禀非完全决定论”则是其逻辑连接的关节点。

其实，在量子测量中，测量前的波函数，遵从的是量子概率的演化规律，具有相干性，“内禀非完全决定论”是其重要的理论基础，“虚质点、实体波”是其物理实在(曲率模型)；而测量后的波函数，遵从的是宏观经典概率的演化规律，没有相干性，决定论是其重要的基础，“实质点、虚波”是其物理实在(质点模型)。测量使“粒子将不再处于原来的量子态”，而且使波函数的性质发生了根本的变化。前者是

“内禀非完全决定论”的，后者是决定论的。两者通过测量进行转化。

例如，双缝实验中，我们引进仪器与被测系统之间的连续作用，测量中波函数因自纠缠，自动退相干到 ψ_A、ψ_B，但 ψ_A、ψ_B 已不再是测量前的 $|A>$、$|B>$，它遵从的是宏观经典概率的演化规律，没有相干性（混合态），是决定论的。当形被忽略，混合态转向经典态时，动量和位置都是“物理实在的要素”，符合爱因斯坦“物理实在”的定义要求。而测量前 $|A>$、$|B>$ 有突变性，遵从量子概率的演化规律，有相干性（纯态）。说“非决定论”是上帝的赋予不行，那是强词夺理或者是一种无奈。我们必须追究非决定论怎样来源于决定论。“非决定论”是微观世界非连续作用及微观客体“形”不能忽略造成的。量子力学中的“物理实在”与宏观经典力学中的“物理实在”不一样，它由物质波波长建构的“形”（曲率）及“虚质点”组成，是波粒二象性的统一。物理实在的变化，必然带来与之对应的物理实在要素性质的改变。不确定性是在对微观客体进行测量时“形”不能忽略及作质点抽象时理论赋予的，而不是上帝的恩赐。这样爱因斯坦“上帝不会掷骰子”问题也就迎刃而解了。所以，我们称量子力学中的“非决定论”为“内禀非完全决定论”。

量子力学是描述微观世界的基本理论，它的一些基本概念与宏观经验有矛盾，这是理论层次之间的矛盾，可以认识，并且可以相互沟通的。测不准关系的实在论背景诠释，就是解决这一问题的。

EPR 佯谬的第二部分是论证量子力学理论是不自洽的，具体体现在量子力学中对波函数的描述不自洽。[6]

Einstein 考虑两个粒子①加②组成的体系，在 $t(0,T)$ 时间内有相互作用，而在 $t>T$ 后，①和②粒子彼此远离，不再有任何相互作用，设 $t=0$ 时刻①+②的量子态已知，借助 Schrödinger 方程，可以预言以后任何时刻，尤其是 $t>T$ 时的量子态。设用 $\psi(x_1,x_2)$ 表示二粒子体系的量子态，x_1 和 x_2 分别代表两粒子的全部坐标。在 $t>T$ 后，分别对力学量 $\hat{A}$、$\hat{B}$ 进行测量（$[\hat{A},\hat{B}]\neq 0$）：

（1）测量粒子①的力学量 $\hat{A}$

设 $\hat{A}u_n(x_1)=a_n u_n(x_1)$，$a_n$ 和 $u_n(x_1)$ 分别是 $\hat{A}$ 的本征值和本征态，$n=1,2,3\cdots\cdots$ 将 $\psi(x_1、x_2)$ 按 $\hat{A}$ 的本征态 $u_n(x_1)$ 展开，则有

$$\psi(x_1,x_2)=\sum_n \psi_n(x_2)u_n(x_1) \tag{6.12}$$

(6.12)式中 $\psi_n(x_2)$ 是 $\psi(x_1,x_2)$ 按 $\hat{A}$ 的本征态 $u_n(x_1)$ 展开的系数。$\psi_n(x_2)$、$u_n(x_1)$ 具有非连续编号属性，构成纯量子态。

(6.12)式中的波函数都是符合量子概率的演化规律的，具有相干性。量子测量中，如果测得的结果为 a_k，按正统量子力学观点，测量将导致波包坍缩到

$$\psi(x_1,x_2)\xrightarrow{\text{测量}}\psi_k(x_2)u_k(x_1) \tag{6.13}$$

测量后的波函数是混合态，它符合宏观经典概率的演化规律，不存在相干性。测量——宏观仪器连续作用的介入，使得由 $\psi_n(x_2)$、$u_n(x_1)$，$\psi_k(x_2)$、$u_k(x_1)$ 构成的波函数的性质发生了从纯量子态到混合态的变化。

(2)测量粒子①的力学量 $\hat{B}$

设 $\hat{B}V_s(x_1)=b_sV_s(x_1)$，$b_s$ 和 $V_s(x_1)$ 分别是 $\hat{B}$ 的本征值和本征态，$S=1,2,3\cdots\cdots$ 将 $\psi(x_1,x_2)$ 按 $\hat{B}$ 的本征态 $V_s(x_1)$ 展开，则有

$$\psi(x_1,x_2)=\sum_s \psi_s(x_2)V_s(x_1) \tag{6.14}$$

其中 $\psi_s(x_2)$ 是 $\psi(x_1,x_2)$ 按 $\hat{B}$ 的本征态 $V_s(x_1)$ 展开的系数。$\psi_s(x_2)$、$V_s(x_1)$ 具有非连续编号属性，亦构成纯量子态。

(6.14)式中的波函数符合量子概率的演化规律，具有相干性。进行量子测量，如果测得的结果为 b_k，则测量将导致波包坍缩到

$$\psi(x_1,x_2)\xrightarrow{\text{测量}}\psi_r(x_2)V_r(x_1) \tag{6.15}$$

同样，测量后的波函数也是混合态，符合宏观经典概率的演化规律，不存在相干性。测量——宏观仪器连续作用的介入，使得由 $\psi_s(x_2)$、$V_s(x_1)$ 与 $\psi_r(x_2)$、$V_r(x_1)$ 构成的波函数的性质发生了从纯量子态到混合态的变化

量子测量的上述哥本哈根解释，让爱因斯坦不解。爱因斯坦认为，在 $t>T$ 后，①和②已彼此远离，不再有任何相互作用，因此，对粒子①进行任何测量，都不应影响粒子②的量子态。也就是说，既然①与②已经远离，之间没有任何相互作用，测量①、②怎么会跟着坍缩呢(即②也跟着被测量)？难道①②之间有超光速传播信息存在？此外，正统量子力学还有一个尴尬，那就是测量后，粒子②可以处于

$\psi_k(x_2)$ 或者 $\psi_r(x_2)$ 两种不同的状态。这可能吗?

所以爱因斯坦认为,量子力学是不自洽的。

玻姆把爱因斯坦 EPR 佯谬作了简化,考虑处于自旋单态,自旋为$\frac{1}{2}$的二粒子体系。当 $t \geqslant T$ 以后,两粒子之间已经不再有相互作用,测量粒子 A 的自旋,不应对粒子 B 的自旋有任何影响。玻姆对 EPR 的表述比爱因斯坦原文更为简单,所以,后来对 EPR 佯谬的争议,大多以它作为讨论的对象。

对 EPR 佯谬的理解,实际上涉及到对量子力学中纠缠态的理解。按纠缠态的定义,它是二粒子体系本征态的直积形式的线性叠加。数学形式上是二粒子的"态",通过直积的叠加彼此关联,形成一个整体。按正统量子力学的解释,波函数是概率波,因此它的纠缠是概率的纠缠。在量子力学曲率解释中,波函数是曲率波,描述微观客体"形"的变化规律,因此,它的纠缠是"形"的纠缠。更本质地说是"曲率"的纠缠,是空间的纠缠。[7]两个粒子不管远离还是不远离,空间的纠缠总把它们维持为一个整体。爱因斯坦强调的二粒子的纠缠是二粒子之间的相互作用的纠缠。一个纯量子态,能按爱因斯坦想像的相互作用方案去建立吗? 按第四章中的定性分析,结论是:不能。

在玻姆的自旋量子态中,自旋向上$|\uparrow\rangle$和自旋向下$|\downarrow\rangle$是可以突变的。测量粒子 A 的自旋,按照我们的理解,是连续作用的介入,粒子 A 的自旋向上$|\uparrow\rangle_A$与自身的自旋向下$|\downarrow\rangle_A$关联,使得粒子 A 自身的自旋状态由突变变成连续,相干退去,回到宏观经典世界。而粒子 B 的自旋向上$|\uparrow\rangle_B$,在构造粒子 A、B 的纠缠态中,已通过直积形式与粒子 A 的自旋向下$|\downarrow\rangle_A$相关联($|\downarrow\rangle_A|\uparrow\rangle_B$),因此,测量粒子 A 必然通过空间纠缠对粒子 B 有影响。粒子 B 的自旋状态通过与粒子 A 的直积关联,回到宏观经典世界。由于波函数的空间特性,A、B 之间的联系完全是空间的联系,而非相互作用的联系。它是一种非能量的信息联系,可以超过光速。

此外,宏观运动的左旋和右旋两种状态,突变只能是观念上的。如果进行力学分析,两种状态的转变之间一定具有连续作用机制存在,因此,自旋量子态不能等同宏观的左旋和右旋状态,实际的物理作用不能与观念上的突变混为一谈。从微观到宏观的转变,一定少

不了量子测量。少不了相互作用机制的转变。我们不能利用数学的便捷，将不同性质的事物结合在一起，引起认识上的混乱。过去我们之所以在多粒子量子态上纠缠不清，关键是对宏、微观作用机制的区别及它们与量子态的关系关注不够。[8]

可见二粒子的纠缠是"形"的纠缠。量子测量中的超光速信息，它的传播是非能量的信息传播。量子计算机的设计必须考虑微观非连续作用机制向宏观连续作用机制的转换，也就是要设计一个量子测量机制，让量子概率转换到宏观经典概率。转换中信息是否丢失，是值得考虑的。但不管怎样，量子编码总是可以实现的。

对 EPR 论证和薛定谔猫的分析，将直接帮助我们理解量子测量中仪器干扰问题的本质。所谓仪器的干扰，就是微观客体与仪器之间连续作用的介入，系统从微观作用机制进入宏观作用机制，不可逆的测量过程就产生了。很明显，当相互作用机制由微观不连续向宏观连续过渡时，微观客体"离散"的形产生了"自纠缠"，由"非局域"向"局域"转化，当"局域形"在讨论的问题中可忽略时，我们对客体态的描述，也由对其时空中"形"的描述，转而对其时空中宏观质点轨迹的描述或质点概率分布的描述。[9]客体的"状态"由微观变化的"形"向宏观质点收缩，是一个由非连续作用向连续作用过渡的过程。

第三节　量子退相干解释的再思考

物理学家贝尔(John Bell)指出："在量子测量理论中，量子相干的消失，是哲学讨论的基石。"[10]哥本哈根学派的传统解释认为，互补原理和测不准关系是引起被测系统(S)量子退相干的一个重要原因。然而人们在问，这是不是退相干现象唯一的直接原因？冯·诺依曼测量理论虽然体现了量子理论的普适性，但波包坍缩最终还得借上帝或人的思维。这让人更加难以理解。一些不满意对"波包坍缩"问题做主观解释的物理学家则另辟蹊径。玻姆(D. Bohm)、埃弗雷特(H. Everett)等，先后在 1952 年和 1957 年提出了隐变量理论和多世界解释。到了 20 世纪 80～90 年代，朱瑞克(W. H. Zurek)等一批物理学家的研究则进一步表明：宏观物体相干性的消失，是环境诱导退相干的结果。[11]朱瑞克等人的研究，最终导致了量子测量退相

干解释。

一、量子退相干解释的基本思路

量子退相干解释的基本思路可归纳如下：

（一）宏观客体具有量子相干性

量子力学作为一个普适理论，可以描述宏观客体乃至宇宙。即宏观客体和宇宙均可以写成满足薛定谔方程演化规律的纯态波函数。因而，宏观客体也具有量子相干性。

（二）外部和内部环境均可诱导宏观物体退相干

由于外部环境或内部环境影响，宏观客体通常能很快（或瞬间）退去相干性。因此，现实生活中，我们看不到宏观物体的相干叠加。外部环境可以是空气中的分子、原子，也可以是辐射中的光子，甚至宇宙微波背景辐射也可以包括在内。内部环境影响，则是宏观物体无规则运动的大量内部自由度。宏观物体既可与外部环境纠缠，也可以与内部环境纠缠，从而导致相干性的消失。

（三）没有内部耗散的系统，也就没有退相干

宏观物体与环境耦合有能量耗散。一般，有耗散就有退相干发生，没有内部耗散的系统，也就没有退相干效应。如果宏观物体与其环境（外部或内部自由度）没有耦合或弱耦合，从而没有耗散效应，系统的量子干涉就会保留。这可以用来说明超导和超流体，尽管它们也有许多内部自由度，却可以保持宏观量子叠加态。

总之，布朗运动式涨落和耗散是导致退相干的根源，但主要是布朗运动式涨落的影响。

二、退相干解释在量子测量具体模型中的应用

仪器（M）与被测系统（S）的关联：

冯·诺依曼测量理论指出，量子测量操作是从仪器（M）的状态“读出”被测系统（S）的状态。[12]用量子力学描述这种“读出”过程，就必须有被测系统（S）和测量仪器（M）之间的关联。若 $|\psi\rangle=\sum_n c_n|n\rangle$ 是被测系统（S）的初态，而 $|e\rangle$ 是仪器（M）的初态，则量子纠缠可以由系统（S）加仪器（M）形成的总系统（S＋M）的

波函数(因子化初态):

$$|\psi_{总}(0)>=\sum_{n}c_n|n>|e> \tag{6.16}$$

描述。根据退相干理论,量子纠缠告诉我们,对于不可因子化的末态

$$|\psi(t)\rangle=\sum C_n(t)|n>|e_n>$$

$|e_n>$是仪器的末态,$n=1,2,3\cdots\cdots k$

一旦测量发现仪器(M)处于$|e_k>$,我们就知道总系统(S+M)处于分量$|k>|e_k>$,即整个波函数“坍缩”到了$|k>|e_k>$上,并判定被测系统(S)处于$|k>$上。

必须注意,(6.16)式中系统(S)和仪器(M)的波函数均是纯量子态。根据退相干解释的基本思路,量子测量的上述操作可归纳为简式:

系统(S)和仪器(M)均处于纯量子态($|n>$、$|e>$)→构建系统(S)和仪器(M)之间的量子纠缠态$|\psi(0)>$→宏观仪器(M)的初态$|e>$自动退相干到$|e_n>$→发现仪器(M)处于$|e_k>$态上→被测系统(S)跟着退相干到$|k>$态(混合态)上。

这就是退相干解释在量子测量上述具体模型中的应用。作为一种应用模型,(6.16)式的思路是清晰的,但逻辑是不自洽的,并仍然保留有“波包坍缩”的困难。

其一,既然宏观客体包括仪器(M)可以很快或瞬间退相干,那么,一台测量仪器(M)一旦“出生”,很快或瞬间它就会从“纯态”演化到“混合态”,而且这种演化是不可逆的。

其二,用仪器(M)去测量量子系统(S),由于原因(一),测量前仪器(M)就已退相干成为混合态。因此,任何实际测量中不可能有“纯态”形式存在的仪器(M)。说M和S相互作用时,M能处于理想状态(纯态)只能是梦想。(6.16)式的理想状态只有数学操作意义,而没有实际物理意义。

其三,要想(6.16)式有实际物理意义,要么宏观仪器(M)在与被测系统(S)耦合之前,不能退相干。我们必须狠心地让“仪器猫”不死不活地等在那里。这与退相干解释关于宏观客体能很快或瞬间退相干的基本理论相违背;要么宏观仪器(M)可很快或瞬间退相干,但在与被测系统(S)耦合之前的瞬间自动退回到纯量子态,然后再按

退相干解释的基本思路，带着被测系统(S)退相干回到混合态。这显然有违纯态→混合态演变不可逆的量子测量原理和实验实事。

其四，知道仪器(M)处于$|e_k>$态上，整个波函数(S+M)就坍缩到$|k>|e_k>$态上，从而断定系统(S)处于$|k>$态。由于(6.16)式逻辑不自洽，测量前M就已退相干，宏观仪器(M)退相干所需时间，对被测系统(S)"波包坍缩"没有贡献，因而"波包坍缩"疑难并没有消除。

基于上述四点原因，我们认为(6.16)式所描述的退相干操作，只是一个"为了实用目的"而构造的数学操作，它不代表任何实际的物理过程，没有任何物理意义。最令人头痛的"波包坍缩"疑难在该模型中仍然保留着。

对宏观猫的自动退相干分析，同样难逃上述命运。在薛定谔猫笼中，"猫"作为带动衰变原子退相干的"仪器(M)"，在现今自动退相干操作模式中，它的命运并没有好到哪里去。可怜的猫，要不只有不死不活地等着，一旦原子衰变系统(S)放进笼子，它开始退相干，带着原子一起回到宏观世界；要不只有独自自动退相干之后，在衰变原子放进笼子的瞬间，再回到不死不活的状态，然后再带领衰变原子退相干。这两种情形都是违背量子力学基本原理的。

显然，量子退相干解释的现有操作模式，不能逻辑自洽地解释量子测量问题。

三、量子纠缠自动退相干解释的新思考

新思考的基本思路是：

①冯·诺依曼假设—宏观物体的"纯量子态"在退相干理论中只有象征意义，因为宏观物体一旦"出生"，它就瞬间退相干变成了混合态。任何实际的测量仪器(M)，在量子测量中只能以混合态的形式出现。

②量子测量实质是宏观仪器(M)为被测系统(S)提供一个连续作用机制，消除本征态之间的突变性、相干性消失，纯态变成混合态。

③混合态的仪器(M)识别的是混合态的被测系统(S)，而且这种识别具有随机性。

④被测系统(S)退相干，纯态向混合态的转化，体现了微观量子

世界与宏观经典世界，理论描述的物理实在结构上的转化。

下面我们以二能级微观粒子为例，建立退相干模型。

若$|A>$、$|B>$为微观粒子二能级纯量子态分支，ψ_A、ψ_B是测量后对应的混合态分支。我们认为测量中$|A>$向ψ_A转化，$|B>$向ψ_B转化是一个真实的物理过程。因此，$|A>$与ψ_A，$|B>$与ψ_B之间具有了量子关联。量子测量只是为被测系统(S)提供一个由状态突变到状态连续的环境改变。被测系统(S)的退相干，是测量前、后系统(S)自身状态纠缠的产物。按照上述思路，我们作出自纠缠态：

$$\psi=\psi_A\otimes|A>+\psi_B\otimes|B> \tag{6.17}$$

(6.17)式类似于"通过 Rabi 转动把描述原子走哪条路径的空间状态ψ_B和ψ_C与原子内部状态$|2>$和$|3>$关联起来形成所谓的纠缠态。

$$\psi_T=\psi_B\otimes|2>+\psi_C\otimes|3>$$

从而发现，在不改变原子动量的条件下，对原子的空间运动作如上的内态标记后，ψ_B、ψ_C间的干涉条纹就消失了。"[13]

(6.17)式中，测量前的状态$|A>$和$|B>$，被看作是微观客体的一种内部状态(纯量子态)，ψ_A、ψ_B则是测量后的混合态，仪器M对系统S的连续作用，在$|A>\rightarrow\psi_A$，$|B>\rightarrow\psi_B$的转化中当被看作内动力。但这种内动力却改变了原纯态波函数的突变性质，在自纠缠态中实现了纯态向混合态的转化。

上述模型可应用到对双缝实验和薛定谔猫的分析上。双缝提供了一个电子波函数的二能级分支。测量前的电子波函数$|A>$、$|B>$是纯量子态，它可以看作是电子的内部态(双缝的间隔类似制造突变区)，而测量后的态ψ_A、ψ_B则是电子的混合态。作如(6.17)式的自纠缠态，对内态标记，即可实现电子的退相干。量子测量只是提供了一个作用连续的，系统(S)内部的转化动力。

对于薛定谔猫，我们也可以让纯态的活猫－$|A_{活}>$，死猫－$|A_{死}>$，分别向混合态的活猫－$\psi_{活}$，死猫－$\psi_{死}$转化，内外环境影响及能量耗散，则只是提供系统(S)内纯态向混合态转化的连续作用机制。于是猫的退相干自纠缠态可写成：

$$\psi=\psi_{活}\otimes|A_{活}>+\psi_{死}\otimes|A_{死}> \tag{6.18}$$

(6.18)式中的$|A_{活}>$、$|A_{死}>$是猫退相干之前的纯量子态(可看作猫的内部态)，$\psi_{活}$、$\psi_{死}$是猫的混合态，$\otimes$表示纯态向混合态转化所需的

连续作用机制提供的关联。对(6.18)式中 ψ 求概率分布作内部纯态标记,即可实现猫的瞬间自动退相干。[14]

总之,量子力学曲率解释[15][16]中的量子测量理论可简要表述如下:

①不需要波包坍缩。

测量中不存在波包坍缩,只有连续作用的介入引起被测系统的自纠缠、自动退相干。

②波函数的每一分支均平行存在并与宏观世界对应。

微观世界,比如原子中,不同能级的波函数分支彼此都是平行存在的。不同能级之间能量不连续,作用不连续,是突变的,可构成独立的相干波源。但每个能级对应的本征函数分支自身都是连续、单值、周期函数。这样,每个能级的本征函数都可以与宏观世界对应。微观客体的宏观粒子信息,均包含在与该本征态对应的振幅(基准曲率)之中。

③量子测量过程,就是消除突变或消除独立相干波源的过程。在自纠缠、自动退相干中,广域的相干波消失了,而宏观"局域"形态的粒子却产生了。德布罗意梦寐以求的"波收进粒子","粒子展现成波"的过程,在这里终于得到了理想的说明。

④测量中仪器(M)对本征值的识别具有随机性。

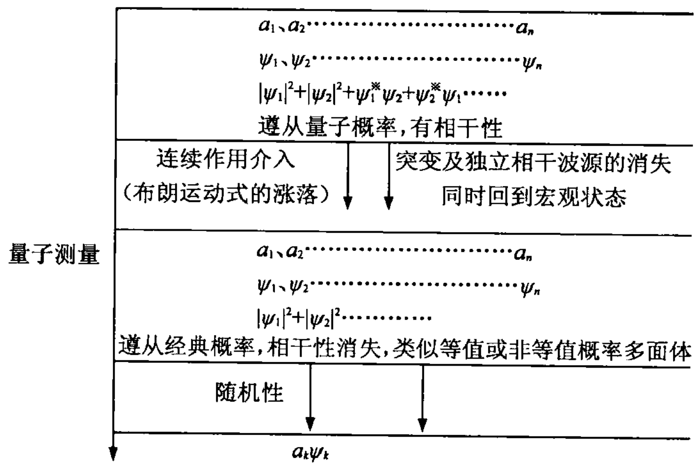
仪器(M)对被测系统(S)的连续作用,迫使千军万马的本征态都在自纠缠中同时向宏观世界转化。至于哪一个本征态的本征值能被仪器(M)捕捉,却是随机的。但靠近原子核的本征态的本征值被识别的机会多些,概率也高,反之亦反。当某一能级本征态的本征值被仪器(M)确切捕捉时,则其出现的概率就转化为1。至于为什么这一次是这一本征态的本征值被测到,原因是不知道的,只有概率统计规律。

⑤人与测量仪器(M)同属宏观世界。

仪器(M)是宏观客体,利用内外环境影响就可自动退相干,仪器(M)的运动是宏观决定论的。人与宏观仪器(M)同属宏观客体,人只对连续作用有经验上的感知,人的观察运动也是决定论的。因此,人与测量仪器(M)同属宏观世界。仪器(M)显示的读数,就是人认知的读数。测量过程是通过连续作用的介入,迫使量子概率向宏观

经典概率转化，并让人获取经验感知的过程。量子力学曲率解释不需要多重世界，只需要宏观与微观两个世界。

量子测量过程可由下图作出展示：



量子力学曲率解释，有可能为消除相对论与量子力学之间的深层矛盾提供契机。它的直接结果是：

①微观领域，原子中没有独立不变的电子，电子的"形"是可变的，原子中的电子不同于从原子中分离出来的电子，电子的"现象实体"，原子内外发生了变化，传统的分析还原有局限性；

②宏观质点的抽象原则不适用于微观世界原子深处的电子；

③量子力学描述的物理实在，不同于经典力学中的质点，量子力学中原子深处的物理实在是曲率波与虚质点的结合，是波粒二象性的统一；

④要想把不同认识层次的事物统一到同一认识层次上是办不到的。我们能做的是找出不同认识层次之间的逻辑接口；

⑤考虑到量子测量中的信息丢失，量子计算机的实现，必须有连续作用到非连续作用的逆过程。

⑥"冻僵"了的原子之间无能量耗散，可建立起宏观的"纯量子态"。这可能为量子计算机的研发提供原理上的保证。但如何保证人能生活在这个"冻僵"的世界呢？

参考文献

[1] 曾谨言,等. 量子力学新进展[M]. 北京:北京大学出版社,2000:70.

[2] 曾谨言,等. 量子力学新进展[M]. 北京:北京大学出版社,2000:105.

[3] 赵国求. 消除相对论与量子力学深层矛盾的新思路//科学技术与辩证法[J],2005(1).

[4] 曾谨言,等. 量子力学(上、下)[M]. 北京:科学出版社,1995:172-173.

[5] M.雅默. 量子力学哲学[M]. 秦克诚,译. 北京:商务印书馆,1989:70.

[6] 曾谨言,等. 量子力学(上、下)[M]. 北京:科学出版社,1995:192-199.

[7] 吴国林. 量子纠缠及其哲学意义//自然辩证法研究[J],2005(7).

[8] 赵国求. 消除相对论与量子力学深层矛盾的新思路//科学技术与辩证法[J],2005(1).

[9] 赵国求,桂起权,等. 物理学的新神曲[M]. 武汉:武汉出版社,2004:第二版,220-222.

[10] J. S. Bell. On Wave Packet Reduction in the Coleman Hepp Model, Helv, Phys, Acta(J)1975(1):48,93-98.

[11] 李宏芳. 量子力学的退相干解释及哲学//自然辩证法通讯[J],2005(2).

[12] 孙昌璞. 量子退相干问题//量子力学新进展(1)[M]. 北京大学出版社,2000:70.

[13] S. Dure, T. Nonn, and G. Rampe, Nature 395,33(1998).

[14] 赵国求,桂起权,等. 物理学的新神曲[M]. 武汉:武汉出版社,2004:217-222.

[15] 赵国求,桂起权. 薛定谔方程的描述对象及量子力学曲率解释中的波粒统一//第十三届国际逻辑、方法论及科学哲学大会报告论文,2007(8).

[16] 赵国求. 物理学与哲学之间——相互作用实在与量子力学曲率解释. 中国新闻联合出版社,2005:208-218.

Chapter 7
Physical Essence and Philosophical Thinking of Arthur H. Compton Matter Wave & Gauge Transformation

7.1 Arthur H. Compton Matter Wave & Curvature interpretation in Quantum Mechanics

Theoretically, electron can be used to bombard electron in measuring the size of electron, and then its size can be obtained by observing the scattering of the bombarded electron. As to the radius of a static electron, Compton wavelength of the static electron $\lambda_0 = \frac{\hbar}{m_0 c}$ is often used as measurement in estimation. As to motional electron, owing to $\lambda_c = \frac{\hbar}{mc}$, electric charge distributing radius of particle λ_c will decrease as motion speed of particle increases.

Guided by the above consideration, we will prove that magnetic moment of electron is a Bohr magneton. And we will also point out that magnetic moment of electron decreases with the increase of motion speed.

7.1.1 Compton wavelength and Bohr magneton

Experimental measurement of electron radius indicates, electric charge distributing radius is the same as quantity level of Compton wavelength λ_0; by applying the above concept, it can be

theoretically deducted that magnetic moment of electron is equal to Bohr magneton. Suppose electric charge distributing radius of electron forms circular current in any direction on spherical surface, the radius of circular current is Compton wavelength $\lambda_0 = \frac{\hbar}{m_0 c}$ mentioned previously. And static electron resembles a circular electric field vortex. Because the radius of micro circular current of static electron

$$r_0 = \frac{\hbar}{m_0 c} \tag{7.1}$$

and then the circumference of the circular electric current is:

$$L = 2\pi r_0 \qquad (r_0 = \lambda_0)$$

The period that electric charge e completes a circle is:

$$T = \frac{2\pi r_0}{c} = \frac{2\pi\hbar}{m_0 c^2}$$

In the equation, c is the speed of electric current. And intensity of current is:

$$I = \frac{e}{T} = \frac{e m_0 c^2}{2\pi\hbar}$$

According to the definition of magnetic moment, the magnetic moment of electron is:

$$\begin{aligned} P_{m_0} &= I \cdot \frac{ds}{c} \\ &= \frac{I\pi r_0^2}{c} \\ &= \frac{1}{c} \cdot \frac{e m_0 c^2}{2\pi\hbar} \cdot \frac{\pi\hbar^2}{m_0^2 c^2} \\ &= \frac{e\hbar}{2m_0 c} \end{aligned} \tag{7.2}$$

Now, we have proved that, magnetic moment of electron equals a Bohr magneton $\frac{e\hbar}{2m_0 c}$, and in random direction, because we do not stipulate the winding direction of circular flow on the spherical surface. Theoretical calculation tells us once again, static electron can be looked as the spherome of radius $r_0 = \lambda_0 = \frac{\hbar}{m_0 c}$. If

spherical space attribute of electron is expressed with curvature, the curvature corresponding to the spherical surface is:

$$R_0 = \frac{1}{r_0} = \frac{m_0 c}{\hbar} = \frac{p_0}{\hbar} \tag{7.3}$$

Here, $m_0 c = p_0$ is regarded as certain "momentum" corresponding to static electron. It is dialectics that there is the "dynamic" in the "static".

According to special theory of relativity, particle mass increases with the increase of motion speed, and

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

Now, particle radius decreases with the increase of motion speed.

$$r = \frac{\hbar}{mc} = \frac{\hbar}{m_0 c} \cdot \sqrt{1 - v^2/c^2} = r_0 \cdot \sqrt{1 - v^2/c^2} \tag{7.4}$$

The above result has been proved by the experiments listed in Appendix 2-1. It tells us, circular radius with Compton matter wave wavelength as circumference has internal connection with the spherical radius of electron, that is, Compton matter wave wavelength of electron has certain relation with spherical space feature of electron.

If calculating the magnetic moment of dynamic electron with the radius r of motional electron, we will have:

$$\begin{aligned} P_m &= (e\hbar/2m_0 c)\sqrt{(1 - v^2/c^2)} \\ &= P_{m_0}\sqrt{(1 - v^2/c^2)} \end{aligned}$$

Magnetic moment of motional electron decreases with the increase of motion speed of electron and that is similar to M. Dirac's conclusion, which can be checked by experiments.

When $v = c$, $\quad p_m = 0$

When $v = c$, $r = 0$, electron changes to point. Mass point cannot be said to revolve. Because it has no rotation effects of field, it is only natural that there is no spin, not to say spin moment. Spin and spin moment is the attribute of rotating field model of non-point particle. It is the essence that spin is an effect of theo-

ry of relativity.

7.1.2 Arthur H. Compton matter wave

Theoretically, Arthur H. Compton matter wave that is connected with static electron can be constructed from Compton wavelength. Now, since it has been assumed that the "image" of electron is not negligible, the law of "image" change is to be discussed.

Quantum mechanics points out, frequency connected with static electron is:

$$\nu_0 = \frac{m_0 c^2}{h}$$

$m_0 c^2$ is static energy of electron. Compton wavelength connected with static electron is

$$\lambda_0 = \frac{h}{m_0 c} \quad (\text{or } \lambda_0 = \frac{\hbar}{m_0 c})$$

Thus we construct a plane matter wave connected with static electron—Arthur H. Compton matter wave, and if light speed c is wave speed,

$$\psi_0 = a_0 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)] \qquad (7.5)$$

In equation (7.5), $\boldsymbol{r}$ is displacement vector, say, direction of electron motion. Because $\boldsymbol{p}_0 \perp \boldsymbol{r}$, $\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$, $\boldsymbol{p}_0 = m_0 \boldsymbol{c}$, $E_0 = m_0 c^2$, $\boldsymbol{p}_0$ possesses momentum dimension and so it is called Compton momentum of static electron. By imitating the expression of David Bohm to matter wave,

If $$a_0 = R_0$$

Equation (7.5) can be rewritten to

$$\psi_0 = R_0 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)] \qquad (7.6)$$

$R_0 = \dfrac{m_0 c}{\hbar}$, possessing curvature dimension of curved surface, is the reciprocal of curvature radius.

So Compton static matter wave is curvature wave. It is matter

wave Louis de Broglie imagined and corresponding to static electron. Because $p \cdot r=0$, in fact it is unobservable.

For a motional electron, we can also construct Arthur H. Compton matter wave ψ_c of a dynamic electron by imitating the above method.

$$\psi_c = a_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_c \cdot \boldsymbol{r} - E_c t)] \tag{7.7}$$

In equation (7.7), $\boldsymbol{p}_c = m\boldsymbol{c}$, $E = mc^2$, and if

$$\begin{aligned} a_c &= R_c \\ &= \frac{mc}{\hbar} \end{aligned} \tag{7.8}$$

$\boldsymbol{p}_c = mc$ possesses momentum dimension, $\lambda_c = \frac{h}{mc}(\lambda_c = \frac{\hbar}{mc})$, so, it is called Compton momentum of motional electron, c is wave speed.

From equation (7.8), equation (7.7) can be rewritten to

$$\psi_c = R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_c \cdot \boldsymbol{r} - E_c t)] \tag{7.9}$$

R_c possesses curvature dimension, so ψ_c is also curvature wave.

Next, we will look at the relation between Arthur H. Compton matter wave and Erwin Schrödinger matter wave. From energy relationship of theory of relativity

$$E_c^2 = (mv)^2 c^2 + m_0^2 c^4$$

$$(mc^2)^2 = (mv)^2 c^2 + m_0^2 c^4$$

In the above equation, when two sides are divided by c^2, we get

$$(mc)^2 = (mv)^2 + (m_0 c)^2 \tag{7.10}$$

If

$$\boldsymbol{p}_1 = m\boldsymbol{v}$$

$\boldsymbol{p}_1$ is relativistic momentum of motional electron, so we get

$$p_c^2 = p_1^2 + p_0^2 \tag{7.11}$$

Equation (7.11) indicates, "momentum" $\boldsymbol{p}_c = m\boldsymbol{c}$, $\boldsymbol{p}_1 = m\boldsymbol{v}$, $\boldsymbol{p}_0 = m_0\boldsymbol{c}$, will construct a right angled triangle of momentum (vector), and

$$\boldsymbol{p}_1 \perp \boldsymbol{p}_0$$

written into rector equation: $\boldsymbol{p}_c = \boldsymbol{p}_1 + \boldsymbol{p}_0$ (7.12)

Suppose the direction of $\boldsymbol{p}_1$ and space vector $\boldsymbol{r}$ are the same, substi-

tute equation (7. 12) and relativistic energy equation $E_c = E_k + E_0$ into equation (7. 9) and we get:

$$\begin{aligned}\psi_c &= a_c \cdot \exp\left\{\frac{i}{\hbar}[(\boldsymbol{p}_1 + \boldsymbol{p}_0) \cdot \boldsymbol{r} - (E_k + E_0)t]\right\} \\ &= R_c \cdot \exp\left\{\frac{i}{\hbar}[(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t) + (\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]\right\} \\ &= R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)] \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]\end{aligned} \tag{7. 13}$$

Consider the above equation, if

$$\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$$

$$\psi_c = R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_c t)] \tag{7. 14}$$

In the equation, $\boldsymbol{p}_1 = m\boldsymbol{v}, E_c = mc^2$, equation (7. 14) is wave function of free electron wave in Dirac theory of relativity. It is clear that Dirac plane electron wave is also curvature wave.

In equation (7. 13), if

$$R_c = a_1 R_0$$

then

$$\psi_c = a_1 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)] \cdot R_0 \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]$$

$$\psi_c = \psi_1 \cdot \psi_0$$

$$\psi_1 = a_1 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)]$$

$$\psi_0 = R_0 \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)] \tag{7. 15}$$

Wavelength and frequency of ψ_1 are separately:

$$\lambda_1 = \frac{h}{mv}, \nu = \frac{E_k}{h}$$

E_k is relativistic kinetic energy of electron, and $\boldsymbol{p}_1 = m\boldsymbol{v}$ is relativistic momentum. While the circular radius with λ_1 as circumference is

$$r_1 = \lambda\!\!\!^{-}_1 = \frac{\hbar}{mv}$$

So

$$R_1 = \frac{mv}{\hbar}$$

Now, through $R_c = \frac{mc}{\hbar}$, $R_0 = \frac{m_0 c}{\hbar}$ and $R_1 = \frac{mv}{\hbar}$, let's discuss and determine coefficient a_1 of ψ_1.

Because $$R_c = a_1 R_0$$

$$a_1 = \frac{R_c}{R_0} \tag{7.16}$$

then $$\psi_1 = \frac{R_c}{R_0} \cdot \exp\left[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)\right] \tag{7.17}$$

In equation (7.17), if

$m = m_0$, $\boldsymbol{p}_1 = m_0 \boldsymbol{v}$ $E_k = \frac{1}{2} m_0 v^2$ (m_0 is static mass), $R_c = R_0$, $\boldsymbol{p}_1 = \boldsymbol{p}$,

So, $$\psi = \exp\left[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)\right] \tag{7.18}$$

Equation (7.18) is plane wave of Erwin Schrödinger free electron. It is classical limit of ψ_1. If we further deal with equation (7.18) in case-type normalization, we will get

$$\begin{aligned} \psi &= A \cdot \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \\ &= \left(\frac{p}{2\pi n \hbar}\right)^{-\frac{3}{2}} \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \\ &= (BR)^{-\frac{3}{2}} \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \end{aligned}$$

Here, $R = p/\hbar$ and $B = \frac{1}{2\pi n}$, R possesses curvature dimension. Schrödinger plane electron wave is also curvature wave.

This time, radius of curvature is:

$$r = \hbar / p$$

It is the equal of wavelength $\lambda = h/p$ as circular radius of circumference, and curvature R is also the curvature of this sphere.

Gui Qiquan and Wu Xinzhong believe, the above analysis of Arthur H. Compton matter wave has revealed that Arthur H. Compton matter wave is more fundamental than Louis de Broglie matter wave.

7.1.3 Measurement of curvature interpretation of Arthur H. Compton Plane matter wave

7.1.3.1 Observational effects of static Compton matter wave

For static electron, Louis de Broglie only assumed a "vibration" corresponding to electron, the vibration frequency is

$$\nu_0 = E_0/\mathrm{h}$$

This is not contradictable to our assumption that static electron corresponds to a matter wave. Because in Compton static matter wave

$$\psi_0 = R_0 \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]$$

$\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$, that is, projection in space direction of momentum $\boldsymbol{p}_0 = m_0\boldsymbol{c}$ is equal to zero, and Compton static wave (momentum) exerts no effects in three dimension space, so wave transmission cannot be observed. Besides, in special theory of relativity, Albert Einstein used light as observational signal, while transmission speed of Compton wave is light speed, the event of the same speed and direction cannot be observed with light signal. And this is the physical reason to establish $\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$. When observable wave function is factually constructed, the direction momentum $m\boldsymbol{v}$ (direction of object motion) is usually chosen to be identical as the direction of location movement $\boldsymbol{r}$, and space feature of object itself observed by the humans is always formed in the direction of momentum effect. ψ_c appears through ψ_1. Presently, physicists take static Compton wavelength of particle λ_0 as measurement when particle is static, which is a theoretical agreement. However, from the result of experimental measurement, the value of theoretical agreement coincides with experimental value, which provides experimental basis for us to believe that matter wave is curvature wave.

7.1.3.2 Observational effect of Compton dynamic matter wave

A right angle triangle is constructed among electron's Compton static "momentum" $\boldsymbol{p}_0$, motional "momentum" $\boldsymbol{p}_c$ and relativistic

momentum $\boldsymbol{p}_1$,

$$\boldsymbol{p}_c = \boldsymbol{p}_1 + \boldsymbol{p}_0$$

$\boldsymbol{p}_c$ and $\boldsymbol{p}_0$ construct a slightly declined angle, while $\boldsymbol{p}_1$ and location shift of electron motion in space $\boldsymbol{r}$ are in agreement in direction (in fact, $\boldsymbol{p}_1$ is projection of $\boldsymbol{p}_c$ in direction $\boldsymbol{r}$), so $\boldsymbol{p}_c$ produces fluctuating observation effect of electron through $\boldsymbol{p}_1$ in space direction. When $m = m_0$, Erwin Schrödinger matter wave is observed; if $m \neq m_0$, $\boldsymbol{p}_1$ and E_c construct Dirac matter wave; and "substance of appearance" can be constructed by their wavelength.

7.1.3.3 Significance of plane wave in curvature interpretation of quantum mechanics

In probability interpretation of quantum mechanics, the meaning of plane wave $|\psi|^2$ is that probability density of electron that appears anywhere in space is the same. In curvature interpretation of quantum mechanics, the meaning of plane wave $|\psi|^2$ is understood like this: any particle (substance-in-itself), electron for example, can only be found in interaction, that is to say, its image can only be found when electron momentum changes from static to dynamic state or from dynamic to static state. In curvature interpretation, $|\psi|^2$ is correlated with space image (curvature) of electron, but as to free electron, because no force is exerted on it, its "space image" cannot be shown in its free flight. Electron momentum is formed by momentum difference $\Delta \boldsymbol{p}$ in interaction from static to dynamic state or vice versa. That is to say, the image of free electron in space-time can only be the image just before the electron freely flies. While freely flying, electron "image" (curvature) is unchangeable. In the corresponding relation of curvature and probability, probability will not change if curvature does not change, which is the physical significance of $|\psi|^2 =$ constant. Because no force is exerted on electron and no optical change that reflects electron image, when electron freely flies, we do not know what the electron is like and where it is, which is the significance of plane wave of

electron. To know where electron is, we have to re-exert force effect on it and that is quantum measurement.

In discussed issues, if image of free electron can be ignored, electron wave disappears, electron returns to the category of macro classical mechanical discussion, and electron becomes macro mass point.

Together with the discussion of plane wave normalization method, we find the description of electron may be divided into three different layers according to different environments: The first, in discussed issues, electron "image" cannot be ignored, its "image" is changeable, there is catastrophe between eigenstates, and on each ground vector of Hilbert space, electron simultaneously possesses probability distribution. At this time, particle is virtual (ghost particle) and wave is real. "Virtual matter and real space" is physical 'reality. Now, with independent interference wave sources, state superposition forms physical coherence, and constructs pure quantum state. Electron in atom interior, infinite deep potential well, linear harmonic oscillator, two-slit and so on is suitable to this condition. The second, in quantum measurement, continuous effect interferes, catastrophe disappears and continuous spectrum forms, independent interference wave sources does not exist, and pure quantum state changes to mixed state. The third, in the discussed issue, "image" can be ignored, and particle itself has only corpuscular property but no wave. This is classical state. Electron changes into macro mass point, only mass point is physical reality, and electron moves around orbit. This is classical state in classical mechanics.

7.2 Physical Reality in the Theory of Gauge Field that Introduces Covariant Derivative & its Philosophical Thinking

It is generally considered that interaction between particle and

field is realized through the introduction of gauge field. In fact, local gauge transformation of free particle has put particle into field interaction automatically. When total gauge transformation of free particle transits to local gauge transformation, field interaction changes from "non-existence" to "existence", and gauge invariance is disrupted. Although the introduction of gauge field through covariant derivative reflects the effects of particle and field, it is the neutralization for particle to restore "free state".

7.2.1 Inspiration of classical electromagnetic field gauge transformation

In the theory of classical electromagnetic field, gauge transformation takes up the following mathematical form [1]:

$$\begin{aligned} \boldsymbol{A}' &= \boldsymbol{A} + \nabla\alpha \\ \varphi' &= \varphi - \frac{\partial \alpha}{\partial t} \end{aligned} \tag{7.19}$$

In equation (7.19), $\boldsymbol{A}$ is the vector potential of electromagnetic field, φ is the scalar potential of electromagnetic field, and α is random mathematical function.

7.2.1.1 Local gauge transformation

In equation (7.19), if $\alpha = \alpha(x,t)$, α is function of space-time point, and

$$\nabla\alpha \neq 0 \text{ , } \frac{\partial \alpha}{\partial t} \neq 0$$

now, from equation (7.19), we know

$$\begin{cases} \boldsymbol{A}' \neq \boldsymbol{A} \\ \varphi' \neq \varphi \end{cases} \tag{7.20}$$

And in gauge transformation, we get

$$\boldsymbol{E}' = \frac{\partial \boldsymbol{A}'}{\partial t} - \nabla\varphi' = \frac{\partial \boldsymbol{A}}{\partial t} - \nabla\varphi = \boldsymbol{E} \tag{7.21}$$

$$\boldsymbol{B}' = \nabla\times \boldsymbol{A}' = \nabla\times \boldsymbol{A} = \boldsymbol{B} \tag{7.22}$$

From equation (7.22) and equation (7.20), we know $\boldsymbol{A} \neq 0$. Because $\boldsymbol{A} = 0$, then $\boldsymbol{A}' = 0$ and we get $\boldsymbol{A}' = \boldsymbol{A}$. However, it violates

equation (7.20), so equation (7.20) is changed to:

$$\begin{cases} \boldsymbol{A}' \neq \boldsymbol{A} \neq 0 \\ \varphi' \neq \varphi \neq 0 \end{cases} \tag{7.23}$$

Equation (7.23) indicates, local gauge transformation requires field A not to have zero value. So, combining equations (7.21) and (7.22), we have:

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} \neq 0 \\ \boldsymbol{B}' = \boldsymbol{B} \neq 0 \end{cases} \tag{7.24}$$

Equation (7.24) indicates, in local gauge transformation, the change of vector potential $\boldsymbol{A}$ does not affects field interaction, and because interaction does not change, the change of particle motion condition is not affected. Local gauge invariance reflects invariability of field interaction or particle motion condition in the field.

So, local gauge transformation ($\alpha = \alpha(x,t)$) of equation (7.19) electromagnetic field has the only non-zero value.

7.2.1.2 Global gauge transformation

In equation (7.19), if α = constant, it is called global gauge transformation. And

$$\nabla\alpha = 0$$

$$\frac{\partial\alpha}{\partial t} = 0$$

From equation (7.19), we have:

$$\begin{cases} \boldsymbol{A}' = \boldsymbol{A} \\ \varphi' = \varphi \end{cases} \tag{7.25}$$

Discussion: in equation (7.25), if

① $\boldsymbol{A}' = \boldsymbol{A} \neq 0$, $\varphi' = \varphi \neq 0$, according to equations (7.22) and (7.23), we get:

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} \neq 0 \\ \boldsymbol{B}' = \boldsymbol{B} \neq 0 \end{cases} \tag{7.26}$$

② $\boldsymbol{A}' = \boldsymbol{A} = 0$, $\varphi' = \varphi = 0$, also according to equations (7.22) and (7.23), we get:

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} = 0 \\ \boldsymbol{B}' = \boldsymbol{B} = 0 \end{cases} \tag{7.27}$$

Discussion: 1) and 2) indicate, in gauge transformation described by equation (7.19), for global gauge transformation (α =constant), stipulation of vector potential A is not the only non-zero value, and there is also zero value of electromagnetic field.

7.2.2 Physical essence of covariant derivative introduced by matter wave gauge transformation examined from the angle of dynamics equation

Consider that an electrified particle travel in electromagnetic field with vector potential A and scalar potential φ, its Erwin Schrödinger equation is

$$\begin{cases} i\hbar\dfrac{\partial\psi}{\partial t} = [\dfrac{(\hat{p}-qA)^2}{2m} + q\varphi]\psi \\ i\hbar\dfrac{\partial\psi'}{\partial t} = [\dfrac{(\hat{p}-qA')^2}{2m} + q\varphi']\psi' \end{cases} \tag{7.28}$$

In equation (7.28), transitional relation between A and A' , φ and φ' is determined by equation (7.19), transitional relation of matter wave ψ and ψ' is

$$\psi' = \exp(\frac{iq\alpha}{\hbar})\psi \tag{7.29}$$

Equation (7.29) is the form of gauge transformation of matter wave. In equation (7.29), α is α in equation (7.19) [2]. Similarly,

7.2.2.1 $\alpha=\alpha(x,t)$ is called local gauge transformation of matter wave.

From the discussion in section one, we know that A possesses the only non-zero value, and gauge transformation ensures that field interaction is unchangeable, so is the motion condition of electrified particle. In equation (7.29), ψ' and ψ describe that, the same variable motion condition of electrified particle in filed possesses gauge invariance.

The fact that field possesses the only non-zero value indicates, so long as applying local gauge transformation to matter wave Ψ, it is certain that particle is affected by electromagnetic force in field.

7.2.2.2 α=constant is called the global gauge transformation of matter wave.

①According to equation (7.26), $A' = A \neq 0$, $E' = E \neq 0$ So, ψ and ψ' possess global gauge invariance, also, ψ and ψ' describe the same accelerating motion condition of electrified particle in field.

② According to equation (7.27), $A' = A = 0, E' = E = 0$ So, ψ and ψ' also possess global gauge invariance; ψ and ψ' describe the same uniform motion condition of electrified particle as free particle.

From the discussion of local gauge transformation in matter wave and global gauge transformation, we know, to apply local gauge transformation to matter wave, particle has to be in the filed, while to apply global gauge transformation to matter wave, particle may be in filed or as free particle ($A = 0, E = 0$).

Therefore, when global gauge transformation of free particle transits to local gauge transformation, filed interaction changes from "non-existence" to "existence". The loss of gauge invariance indicates, interaction has changed particle motion condition and what ψ and ψ' describes is not the same motion condition of particle. It is the real physical essence to introduce gauge field through co-variant derivative, neutralize field effect that particle has possessed in local gauge transformation, restore "free state" of particle and settle the lost gauge invariance. Obviously, although the introduction of gauge field reflects the action between particle and field, it is neutralization that particle restores "free state". Bringing to light the above physical essence has important inspiration of physical essence and philosophic significance in gauge transformation

7.2.3 Louis de Broglie matter wave and its essential feature of phase variation

7.2.3.1 Physical essence of matter wave phase

In Special Theory of Relativity, the characteristic of space time of motional object is transferred into the characteristic of space time

of the coordinate system constructed on the object. On the other hand, the process that Louis de Broglie deducted substance wave (as is show below) is the counter process to reduce the characteristic of space time of the coordinate system to characteristic of space time of the motional object.

When Louis de Broglie was deducting equation of matter wave, he once assumed that there was a particle with static mass as m_0 at the original point of inertia system K′, and a wave source caused by vibration corresponding to static particle. [3] It is indicated through analysis that it should be the vibration of virtual mass point of "image interior" constructed by wavelength.

$$\psi = A\sin\omega_0 t_0 \tag{7.30}$$

In which,

$$\omega_0 = 2\pi\nu_0 = \frac{m_0 c^2}{\hbar} \qquad \nu_0 = \frac{m_0 c^2}{h}$$

System K′ is the coordinate system constructed on particle, x_0, t_0 is space-time coordinate of system K′; x, t is space-time coordinate of K; before particle motion, original points of system K, K′ coincide. At the same time, y_0 and y coincide; x_0 and x coincide.

Now, suppose particle (or coordinate system K′ constructed on particle) exerts uniform motion in speed v corresponding to K along positive direction of axis x, which is equivalent to the case that coordinate system K exerts uniform motion in negative direction along x_0 of coordinate system K′.

According to theory of relativity, we have

$$t_0 = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - v^2/c^2}} \tag{7.31}$$

Substitute equation (7.31) into equation (7.30), we have:

$$\psi = A\sin\omega_0 \frac{t - \frac{vx}{c^2}}{\sqrt{1 - v^2/c^2}} \tag{7.32}$$

Given $\omega = \dfrac{\omega_0}{\sqrt{1 - v^2/c^2}}$, $\nu = \dfrac{mc^2}{\mathrm{h}}$, $v_p = \dfrac{c^2}{v}$,

Then equation (7.32) is changed to

$$\psi = A\sin\omega\left(t - \frac{x}{v_p}\right) \tag{7.33}$$

Equation (7.33) just expresses free particle matter wave spreading in positive direction along axis x in system K. it is the transformation of equation (7.14), equivalent to the case that mass effects in special theory of relativity is changed to the phase change of matter wave (the change of frequency ν). See chart 7.1

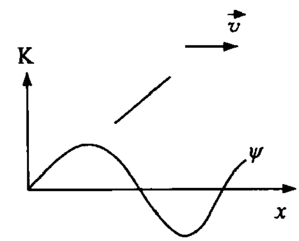


Diagram 7.1 matter wave in system K

The phase velocity of matter wave Ψ is

$$v_p = \frac{c^2}{v}$$

Phase velocity v_p is supper velocity of light.

The lagged phase angle corresponding to original point ($x = 0$) at the time t of the phase position of matter wave ψ at each point of axis x in coordinate K is:

$$\alpha = \frac{\omega x}{v_p} = \frac{\omega v x}{c^2} \tag{7.34}$$

It is known from equation (7.34), if particle has no motion,

Then,
$$v = 0$$
$$\alpha = 0$$

It indicates that, phase change of free particle matter wave ψ depends on particle motion speed v related to matter wave (or speed of coordinate system K′). when $v = 0$, and particle exerts no motion, there will be no observational effect of matter wave in three-dimensional world; if there is no observational effect of matter

wave, there is naturally no phase change in matter wave. When $v \neq 0$, there is observational effect of matter wave in three dimensional time-space, but the corresponding plane wave is only "image" given out by "substance-in-itself" through "substance of appearance", similar to Louis de Broglie "guided wave" (phase wave). Curvature interpretation has explained "phase wave". Matter wave is the description of space-time image of particle itself.

7.2.3.2 Physical sense of initial phase of matter wave

In diagram (7.1), free particle matter wave ψ described by system K is recorded the moment particle leaves initial point $x = 0$. The initial condition is $t = 0$, $x = 0$, initial phase of matter wave $\alpha_0 = 0$. To make the initial phase of matter wave described in system K not equal to zero, record may begin a period of time after particle motion, say, $x = x_0$. Suppose recorded matter wave is ψ', position variable x of matter wave in equation (7.33) should be:

$$x = x_0 + x'$$

Then equation (7.33) is changed to

$$\begin{aligned} \psi' &= A\sin[\omega t - \frac{\omega(x_0 + x')}{v_p}] \\ &= A\sin[-\frac{\omega v x_0}{c^2} + \omega t - \frac{\omega v x'}{c^2}] \end{aligned} \tag{7.35}$$

Note: here, x' is still space-time scale of system K. When $x_0 = 0$, equation (7.35) returns to equation (7.33).

Given
$$\alpha_0 = \frac{\omega v x_0}{c^2} \tag{7.36}$$

And still mark x' with x, so equation (7.35) is changed to

$$\psi' = A\sin[-\alpha_0 + \omega t - \frac{\omega v x}{c^2}] \tag{7.37}$$

α_0 is initial phase of matter wave.. It contains speed factor of particle motion, with specific mathematical structure and physical sense. Equation (7.37) is wave function of free particle matter wave whose initial phase is not equal to zero in system K. Compared with matter wave described by equation (7.33), it only translates

backward for a length of distance the starting point of space that describes the same matter wave motion in the same coordinate system; in mathematics it is coordinate system translation, and in physics it is similar to the initial position of rotator of initial phase of alternating current. See diagram 7. 2.

In diagram 7. 2, matter wave describes the same vibration state of particle in the same reference system. But the different starting points of space of the same substance-recording wave indicate the difference of the initial phase. ψ and ψ' describe the same motion condition of free particle, which is just the requirement of gauge transformation. Relation between initial phase of matter wave and timing zero just reflects physical essence of time change and location x in special theory of relativity. Timing location is different, so equation of time is different and initial phase is different.

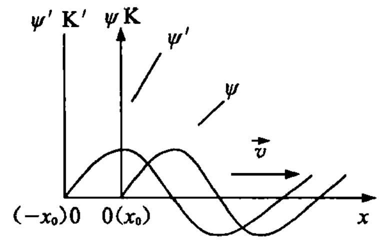


Diagram 7.2 matter wave that initial phase is not equal to zero

7. 2. 3. 3 Physical essence of gauge transformation of Louis de Broglie free particle matter wave

① The whole gauge transformation

Wave function expressed by equations (7. 33) and (7. 37) is written to index function as follows:

$$\psi = Ae^{i\alpha}$$

In which, $$\alpha = \omega t - \frac{\omega v x}{c^2}$$

Suppose $$\alpha' = -\frac{\omega v x_0}{c^2} + \omega t - \frac{\omega v x}{c^2}$$

$$= -\alpha_0 + \alpha$$

So, $$\psi' = Ae^{i\alpha'}$$

$$= Ae^{i(-\alpha_0 + \alpha)}$$

$$= Ae^{i\alpha}e^{-i\alpha_0}$$

Thus, $$\psi' = \psi \cdot e^{-i\alpha_0} \tag{7.38}$$

In equation (7.38), initial phase α_0 = constant, and it possesses the patterns of Abel global gauge transformation and non-Abel gauge transformation. Known from the specific physical implication and mathematical structure α_0, α_0 = constant, which means motion speed of particle connected with matter wave v = constant $\neq 0$ is free particle and exerts uniform motion; and initial position records matter wave $x = x_0$, so equation (7.38) is global gauge transformation equation of free particle of Louis de Broglie matter wave.

According to theory of relativity, $m_0c^2 = h\nu_0$, $mc^2 = h\nu$ and $m = m_0/\sqrt{1 - v^2/c^2}$, mass increase is changed into matter wave frequency and the change of phase indicates that, the increase of total space unity of global gauge transformation of matter wave and gravitational potential of motion particle has intrinsic unity and connection.

② Local gauge transformation

In initial phase,

$$\alpha_o = \frac{\omega v x_0}{c^2} \tag{7.39}$$

In the equation, if $v = v(x,t)$, that is, v is function of space-time point, then $\alpha_0 = \alpha_0(x,t)$, which indicates particle is exerting accelerating motion in force-field.

To substitute $\alpha_0 = \alpha_0(x,t)$

Into equation (7.38), then

$$\psi' = \psi \cdot e^{-i\alpha_0(x,t)} \tag{7.40}$$

Equation (7.40) possesses Abel local pattern and non-Abel local pattern. Local gauge transformation of free particle matter wave indicates that, as long as local gauge transformation is made on free particle matter wave, particle is already positioned in force-field, which further proves that, the action of particle and field has already resulted before gauge field is introduced through covariant

derivative. Although the introduction of gauge field reflects the action of particle and field, it recovers particle's free state and has counteracted the introduction of gauge invariance. [4]

The connection between accelerating motion of particle and local transformation of matter wave indicates that, local gauge transformation is related to the local change of gravitational potential caused by local mass change of motion particle.

7.2.4 Physical essence of introduction of covariant derivative by Yang Cheng Ning—R. Mills gauge field

7.2.4.1 Local gauge transformation

Provided that ψ is wave function of free particle and exerts global gauge transformation on ψ and $\bar{\psi}$, in which α =constant

$$\begin{aligned} &\psi \to \psi' = e^{-i\alpha}\psi \\ &\bar{\psi} \to \bar{\psi}' = \bar{\psi}e^{i\alpha} \\ &\partial_\mu\psi \to \partial_\mu\psi' = e^{-i\alpha}\partial_\mu\psi \end{aligned} \tag{7.41}$$

α =constant, according to the analysis of Broglie free particle matter wave. And then $\partial_\mu\alpha = \partial_\mu v = 0$, corresponding to uniform motion of free particle, there is flow and charge conservation.

Lagrange density of the constructed free field

$$\mathscr{L} = \bar{\psi}\,(\mathrm{i}r^\mu\partial_\mu - m)\,\psi \tag{7.42}$$

Substitute $\bar{\psi}, \psi, \partial_\mu\psi$, $\bar{\psi}', \psi'$ and $\partial_\mu\psi'$ in equation (7.41) into equation (7.42), and we get

$$\mathscr{L}_\psi \to \mathscr{L}_{\psi'} = \mathscr{L}_\psi$$

Substitute $\mathscr{L}_\psi$ and $\mathscr{L}_{\psi'}$ into Lagrange equation

$$\partial\mathscr{L}/\partial\psi - \partial_\mu(\partial\mathscr{L}/\partial\partial_\mu\psi) = 0 \tag{7.43}$$

And we can get the unchanged pattern of Paul A. M. Dirac equation

$$\begin{aligned} &(ir^\mu\partial_\mu - m)\psi = 0 \qquad \text{(a)} \\ &(ir^\mu\partial_\mu - m)\psi' = 0 \qquad \text{(b)} \end{aligned} \tag{7.44}$$

7.2.4.2 Local gauge transformation

In equation (7.41), if $\alpha = \alpha(x,t)$, that is, the turned phase angle is function of space-time coordinate x and t, at this time, there must be $v = v(x,t)$, particle is placed into field to do accelerating motion. To exert local gauge transformation on field energy/quantity and derivative of free particle:

$$\begin{aligned}
&\psi \rightarrow \psi' = e^{-i\alpha(x,t)}\psi && \text{(a)} \\
&\bar{\psi} \rightarrow \bar{\psi}' = e^{i\alpha(x,t)}\bar{\psi} && \text{(b)} \\
&\partial_\mu\psi \rightarrow \partial_\mu\psi' = \partial_\mu[e^{-i\alpha(x,t)}\psi] && \\
&\qquad = e^{-i\alpha(x,t)}\partial_\mu\psi - i\partial_\mu\alpha(x,t)e^{-i\alpha(x,t)}\psi && \text{(c)} \\
&\qquad \neq e^{-i\alpha(x,t)}\partial_\mu\psi &&
\end{aligned} \tag{7.45}$$

Substitute equation (7.45) into Lagrangian density equation (7.42), there is

$$\mathscr{L}_\psi \rightarrow \mathscr{L}_{\psi'} \neq \mathscr{L}_\psi \tag{7.46}$$

Substitute $\mathscr{L}_\psi$ and $\mathscr{L}_{\psi'}$ into Lagrangian equation and it is clear that the pattern of Lagrangian equation and Paul A. M. Dirac equation cannot be kept unchanged. [5]

If $\partial_\mu\alpha(x,t) = \partial_\mu v(x,t) = a_\mu = 0$, particle exerts uniform motion, the second item of (c) in equation (7.45) disappears, which is global gauge transformation of free particle. Field energy/quantity $\psi, \partial_\mu\psi$ and $\mathscr{L}$ possesses gauge invariance. So, when $\alpha = \alpha(x,t)$, the loss of gauge invariance is caused completely by interaction from "nothing" to "being", that is, free particle has been placed in the field $\partial_\mu\alpha(x,t) = \partial_\mu v(x,t) = a_\mu \neq 0$. The accelerating motion of electrical charge destroys flow and charge conservation, as well as the invariance of Lagrangian equation and Paul A. M. Dirac equation. To ensure the invariance of Lagrangian equation and Paul A. M. Dirac equation, counteraction has to be introduced so as to neutralize the action of original field on particle and reduce total acting force to zero, thus ensuring free motion state of electrical charge and realizing gauge invariance. Bring in covariant derivative

$$\partial_\mu \rightarrow D_\mu = \partial_\mu - ieA_\mu \tag{7.47}$$

so as to reach the goal. In the above equation, A_μ is the introduced gauge field. Although the introduction of gauge field reflects the action of electrified particle and electromagnetic field, it is a neutralizing action and people in the past seemed not fully understand this physical mechanism. After the introduction of covariant derivative, Lagrange density is:

$$\mathscr{L} = \overline{\psi}(\mathrm{i}r^\mu \mathrm{D}_\mu - \mathrm{m})\psi \tag{7.48}$$

If A_μ is electromagnetic field, particle stress is electromagnetic force. The total Lagrangian density of interaction between electrified particle and electromagnetic field can be written as:

$$\mathscr{L} = \mathscr{L}_{\psi+\mathrm{i}} + \mathscr{L}_{\mathrm{A}} = \mathscr{L}_{\psi'+\mathrm{i}} + \mathscr{L}_{\mathrm{A}'} \tag{7.49}$$

Substitute equation (7. 49) into Lagrange equation, we have the unchanged pattern of Paul A. M. Dirac equation:

$$(ir^\mu D_\mu - m)\psi = 0 \tag{7.50}$$

We can see that, symmetry of internal space in physical system and invariance of Lagrangian density indicates the physical essence revealed by conservation flow j^i_μ and conservation charge Q^i: Flow and charge conservation just corresponds to uniform motion of load particle; the destroy of gauge invariance indicates the destroy of flow and charge constant, or the destroy of uniform motion state of particle, which is essence of transition from global gauge transformation of free particle to local gauge transformation.

Discussion:

It is generally believed that, the move of internal space in gauge transformation has no relation with external space. However, the discussion in this chapter indicates:

① When matter wave of free particle transits from global gauge transformation to local gauge transformation, the coordinate system K′ constructed on particle also transits from uniform motion to accelerating motion. Introduce gauge field through covariant derivative can restore free motion state of particle.

② Considering there is equivalent "gravitational field" in coor-

dinate system of accelerating motion and "gravitational field" corresponds to heterogeneous space-time, then, global gauge transformation of free particle→ local gauge transformation(electromagnetic field appears)→ loss of gauge invariance, with system K′ constructed on free particle from uniform space-time (uniform motion) →heterogeneous space-time (heterogeneous motion) (gravitational field appears)→ the destroy of space-time uniformity forms organic intrinsic connection. The introduction of gauge field, the recovery of uniform motion of particle and the realization of gauge invariance are equal in value to the introduction of reverse gravitational field and the realization of local straight space-time in the mode of thinking. There is profound intrinsic connection between global gauge transformation of free particle and special theory of relativity, and between local gauge transformation and gravitational field. The above discussion includes counter process of the change of space-time characteristics of particle itself to spaee-time attributes of coordinate system.

③ The discussion in this chapter may have important effect on the physical and philosophic significance in cognition of symmetric destruction in vacuum.

Therefore, we raise the following questions: since transition of electrified free particle from global gauge transformation to local gauge transformation, through covariant derivative, gauge invariance may be achieved by introducing electromagnetic field, if unelectrified free particle is transited from global to local gauge transformation, what will happen when introducing gravitational field through covariant derivative? Does matter wave have gauge invariance or not? Gravitational field has relation with the continuous change of the motional speed of particle, is this that gravitational field cannot be quantized?

Reference

[1] Yu Guangda. Basic Knowledge for Electricians [M]. Beijing: Higher Education Press, 1966:185.

[2] Shi Qingyun. Quantum Mechanics [M]. Beijing:Beijing Institute of Technology Press, 1993:157-158.

[3] He Zuoxiu, et al. Monument of Quantum Mechanics [M]. Guilin:Guangxi Normal University Press, 1994:233-242.

[4] Zhao Guoqiu,Gui Qiquan. et al. New Divine Comedy of Physics [M]. Wuhan:Wuhan Publishing House, 2004:329.

[5] Hu Yaoguang. On Gauge Field [M]. Shanghai: Huadong Normal University Press, 1984:45-51.

第 七 章
康普顿物质波与规范变换的物理实质及哲学思考

第一节　康普顿物质波与量子力学曲率解释

理论上测量电子的大小可用电子去轰击电子，观察击中后电子散射情况，从而测出它的尺寸。对于一个静止粒子，其半径，人们常以静粒子的康普顿波长 $\lambda_0=\frac{\hbar}{m_0c}$ 作为估计线度。对于运动粒子，由于 $\lambda_c=\frac{\hbar}{mc}$，粒子电荷分布半径 λ_c 将随粒子运动速度的增加而减小。

以上述思想作指导，我们将证明电子的磁矩为一个玻尔磁子。指出电子的磁矩随运动速度的增加而减小。

一、康普顿波长与玻尔磁子

电子半径的实验测量表明电子的电荷分布半径与康普顿波长 λ_0 数量级相同，利用上述概念，电子的磁矩等于一个玻尔磁子可以从理论上推导出来。设电子的电荷分布形成球面上任意方向上的环形电流，环形电流的半径就是前面提到的康普顿波长 $\lambda_0=\frac{\hbar}{m_0c}$。静电子像一个环形电场旋涡。因为静电子微环形电流的半径

$$r_0=\frac{\hbar}{m_0c} \tag{7.1}$$

则环形电流的周长

$$L=2\pi r_0 \qquad (r_0=\lambda_0)$$

电荷 e 流动一圈的周期

$$T = \frac{2\pi r_0}{c} = \frac{2\pi\hbar}{m_0 c^2}$$

式中 c 是电流的速度。电流强度：

$$I = \frac{e}{T} = \frac{e m_0 c^2}{2\pi\hbar}$$

按照磁矩的定义，电子的磁矩

$$\begin{aligned} P_{m_0} &= I \cdot \frac{ds}{c} \\ &= \frac{I\pi r_0^2}{c} \\ &= \frac{1}{c} \cdot \frac{e m_0 c^2}{2\pi\hbar} \cdot \frac{\pi\hbar^2}{m_0^2 c^2} \\ &= \frac{e\hbar}{2m_0 c} \end{aligned} \tag{7.2}$$

到此我们证明了电子的磁矩等于 1 个玻尔磁子 $\frac{e\hbar}{2m_0 c}$，而且是任意方向上的，因为我们并没有规定球面上环流的绕向。理论计算再次告诉我们，静电子可看作是半径 $r_0 = \lambda_0 = \frac{\hbar}{m_0 c}$ 的球体。如果用曲率表示此时电子球面空间特性，与球面对应的曲率是

$$R_0 = \frac{1}{r_0} = \frac{m_0 c}{\hbar} = \frac{p_0}{\hbar} \tag{7.3}$$

这里我们把 $m_0 c = p_0$ 看作是与静电子对应的某种“动量”。“静”中有“动”，这就是辩证法。

根据狭义相对论粒子的质量随运动速度的增加而增加，且

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

此时粒子的半径

$$r = \frac{\hbar}{mc} = \frac{\hbar}{m_0 c} \cdot \sqrt{1 - v^2/c^2} = r_0 \cdot \sqrt{1 - v^2/c^2} \tag{7.4}$$

随运动速度的增加而减小。上述结果已由附录 2 中表 2-1 列举的实验所证实。它告诉我们，以康氏物质波波长为圆周的圆的半径与电子球面的半径有某种内在的联系，即电子康氏物质波波长与电子球面的空间特性有某种相关。

如果用运动电子的半径 r 去计算动电子的磁矩，则有

$$P_m = (e\hbar/2m_0c)\sqrt{(1-v^2/c^2)}$$
$$= P_{m_0}\sqrt{(1-v^2/c^2)}$$

运动电子的磁矩随电子运动速度的增加而减小。这与狄拉克的结论相同，应该可由实验检验的。

当 $v=c$ 时　　　$p_m = 0$

当 $v=c$ ，$r=0$ ，电子变成了点。质点无所谓转动，没有场的旋转效应，当然无所谓自旋，也无所谓自旋磁矩。自旋、自旋磁矩是一种非点粒子旋转场模型的特征。这就是自旋是一种相对论效应的实质。

二、康普顿物质波

理论上，由康普顿波长可以构造一个与静电子联系的康普顿物质波。此时，实际已假定电子的"形"不可忽略，讨论"形"的变化规律。

量子力学指出与静态电子联系的频率是

$$\nu_0 = \frac{m_0c^2}{h}$$

m_0c^2 是电子的静能。与静态电子联系的康普顿波长是

$$\lambda_0 = \frac{h}{m_0c} \quad (\text{或}\ \lambda_0 = \frac{\hbar}{m_0c})$$

由此我们构造一个与静电子联系的平面物质波一康普顿物质波，若光速 c 是波速，则

$$\psi_0 = a_0 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0t)] \tag{7.5}$$

(7.5)式中 $\boldsymbol{r}$ 为位移矢量，即粒子运动的方向，由于 $\boldsymbol{p}_0 \perp \boldsymbol{r}$ ，因此 $\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$ ，$\boldsymbol{p}_0 = m_0\boldsymbol{c}$ ，$E_0 = m_0c^2$ ，$\boldsymbol{p}_0$ 具有动量量纲，故称为静电子的康普顿动量。仿照玻姆对物质波的表述，

令　　　$a_0 = R_0$

故(7.5)式可写成

$$\psi_0 = R_0 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0t)] \tag{7.6}$$

$R_0 = \dfrac{m_0c}{\hbar}$ 具有曲面曲率量纲，是曲率半径的倒数。

故康氏静态物质波是曲率波。它是德布罗意设想的与静电子对

应的物质波。由于 $p \cdot r = 0$,实际上它是无法观察的。

对于一个运动的电子,仿照前述方法我们同样可以构造一个动电子康普顿物质波 ψ_c 。

$$\psi_c = a_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_c \cdot \boldsymbol{r} - E_c t)] \tag{7.7}$$

(7.7)中 $\boldsymbol{p}_c = mc$, $E = mc^2$,且令

$$\begin{aligned} a_c &= R_c \\ &= \frac{mc}{\hbar} \end{aligned} \tag{7.8}$$

$\boldsymbol{p}_c = mc$ 具有动量量纲,$\lambda_c = \frac{\text{h}}{mc}$ $(\lambda_c = \frac{\hbar}{mc})$,因此,称其为运动电子的康普顿动量,$c$ 为波速。由(7.8)式(7.7)式可写成

$$\psi_c = R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_c \cdot \boldsymbol{r} - E_c t)] \tag{7.9}$$

R_c 具有曲率量纲,故 ψ_c 也是曲率波。

下面我们来看看康普顿物质波与薛定谔物质波的关系。由相对论能量关系式

$$E_c^2 = (mv)^2 c^2 + m_0^2 c^4$$

$$(mc^2)^2 = (mv)^2 c^2 + m_0^2 c^4$$

上式两边同除以 c^2 ,得

$$(mc)^2 = (mv)^2 + (m_0 c)^2 \tag{7.10}$$

令
$$\boldsymbol{p}_1 = m\boldsymbol{v}$$

$\boldsymbol{p}_1$ 是运动电子的相对论动量。故有

$$p_c^2 = p_1^2 + p_0^2 \tag{7.11}$$

(7.11)式表明,“动量” $\boldsymbol{p}_c = m\boldsymbol{c}$, $\boldsymbol{p}_1 = m\boldsymbol{v}$, $\boldsymbol{p}_0 = m_0\boldsymbol{c}$,将构成一个动量(矢量)直角三角形,且

$$\boldsymbol{p}_1 \perp \boldsymbol{p}_0$$

写成矢量式为
$$\boldsymbol{p}_c = \boldsymbol{p}_1 + \boldsymbol{p}_0 \tag{7.12}$$

设 $\boldsymbol{p}_1$ 与空间矢量 $\boldsymbol{r}$ 的方向相同。将(7.12)式及相对论能量公式 $E_c = E_k + E_0$ 代入(7.9)式得:

$$\begin{aligned} \psi_c &= a_c \cdot \exp\left\{\frac{i}{\hbar}[(\boldsymbol{p}_1 + \boldsymbol{p}_0) \cdot \boldsymbol{r} - (E_k + E_0)t]\right\} \\ &= R_c \cdot \exp\left\{\frac{i}{\hbar}[(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t) + (\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]\right\} \end{aligned}$$

$$= R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)] \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)] \tag{7.13}$$

考虑到上式中

$$\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$$

则

$$\psi_c = R_c \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_c t)] \tag{7.14}$$

式中 $\boldsymbol{p}_1 = m\boldsymbol{v}, E_c = mc^2$,(7.14)式正是狄拉克相对论自由电子波波函数。可见狄拉克平面电子波亦是曲率波。

令(7.13)式中

$$R_c = a_1 R_0$$

则

$$\psi_c = a_1 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)] \cdot R_0 \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)]$$

$$\psi_c = \psi_1 \cdot \psi_0$$

$$\psi_1 = a_1 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)]$$

$$\psi_0 = R_0 \cdot \exp[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)] \tag{7.15}$$

ψ_1 的波长、频率分别是

$$\lambda_1 = \frac{h}{mv}, \nu = \frac{E_k}{h}$$

E_k 是电子相对论动能，$\boldsymbol{p}_1 = m\boldsymbol{v}$ 是相对论动量。而以 λ_1 为圆周长的圆的半径

$$r_1 = \lambda_1 = \frac{\hbar}{mv}$$

故

$$R_1 = \frac{mv}{\hbar}$$

现在通过 $R_c = \frac{mc}{\hbar}, R_0 = \frac{m_0 c}{\hbar}, R_1 = \frac{mv}{\hbar}$,讨论确定 ψ_1 的系数 a_1 。

由于

$$R_c = a_1 R_0$$

$$a_1 = \frac{R_c}{R_0} \tag{7.16}$$

故
$$\psi_1 = \frac{R_c}{R_0} \cdot \exp\left[\frac{i}{\hbar}(\boldsymbol{p}_1 \cdot \boldsymbol{r} - E_k t)\right] \qquad (7.17)$$
令(7.17)式中

$m = m_0, \boldsymbol{p}_1 = m_0 \boldsymbol{v}\quad E_k = \frac{1}{2} m_0 v^2$($m_0$ 为静质量)则，$R_c = R_0, \boldsymbol{p}_1 = \boldsymbol{p}$，

故
$$\psi_1 = \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \qquad (7.18)$$

(7.18)式正是薛定谔自由电子平面波。它是 ψ_1 的经典极限。如果对(7.18)式再进行箱式归一化处理，即得

$$\begin{aligned}\psi &= A \cdot \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \\ &= \left(\frac{p}{2\pi n \hbar}\right)^{-\frac{3}{2}} \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right] \\ &= (BR)^{-\frac{3}{2}} \exp\left[\frac{i}{\hbar}(\boldsymbol{p} \cdot \boldsymbol{r} - E_k t)\right]\end{aligned}$$

这里 $R = p/\hbar$、$B = \frac{1}{2\pi n}$，R 具有曲率量纲。薛定谔平面电子波也是曲率波。

此时的曲率半径

$$r = \hbar/p$$

它相当于波长 $\lambda = h/p$ 作为圆周长的圆的半径，曲率 R 也即为此圆的曲率。

桂起权和吴新忠认为，对康普顿物质波的上述分析，揭示了康普顿物质波比德布罗意物质波更加基本。

三、康普顿平面物质波曲率解释中的测量问题

(一)静态康普顿物质波的观察效应

对于静止的电子，德布罗意实际上只假设了与电子对应的一个“振动”，振动的频率是

$$\nu_0 = E_0/h$$

这与我们假设与静电子对应一种物质波不相矛盾。因为康氏静态物质波

$$\psi_0 = R_0 \exp\left[\frac{i}{\hbar}(\boldsymbol{p}_0 \cdot \boldsymbol{r} - E_0 t)\right]$$

中 $\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$，即动量 $\boldsymbol{p}_0 = m_0\boldsymbol{c}$ 在空间方向上的投影等于零，康氏静态波（动量）在三维空间方向上没有作用效应，波的传播观察不到。此外，在狭义相对论中，爱因斯坦用以观察的信号是光，而康氏波的传播速度是光速，与光同速同向的事件，用光信号是观察不到的。这正是设定 $\boldsymbol{p}_0 \cdot \boldsymbol{r} = 0$ 的物理原因。在实际构造可观察的波函数时，人们总是把动量 $m\boldsymbol{v}$（物体运动方向）与位移 $\boldsymbol{r}$ 的方向选择一致，人类观察到的物体自身的空间特性的形成总是在动量作用的方向上。ψ_c 通过 ψ_1 得以呈现。目前物理学家们把粒子静态康氏波长 λ_0 作为粒子静态时的线度，那是理论上的约定。但从实验测量的结果看，理论约定值与实验值吻合得较好。这为我们认定物质波是曲率波提供了实验依据。

（二）康氏动态物质波的观察效应

由于电子的康氏静止"动量"$\boldsymbol{p}_0$、运动"动量"$\boldsymbol{p}_c$，相对论动量 $\boldsymbol{p}_1$ 之间构成了一个直角三角形，

$$\boldsymbol{p}_c = \boldsymbol{p}_1 + \boldsymbol{p}_0$$

$\boldsymbol{p}_c$ 与 $\boldsymbol{p}_0$ 构成了一微小的偏角，而 $\boldsymbol{p}_1$ 与电子运动的空间位移 $\boldsymbol{r}$ 方向一致（实际上 $\boldsymbol{p}_1$ 是 $\boldsymbol{p}_c$ 在 $\boldsymbol{r}$ 方向的投影），因此 $\boldsymbol{p}_c$ 通过 $\boldsymbol{p}_1$ 在空间方向上产生了电子的波动观察效应。当 $m = m_0$ 时，观察到的是薛定谔物质波；$m \neq m_0$，则由 $\boldsymbol{p}_1$，E_c 构成狄拉克物质波；由它们的波长可建构"现象实体"。

（三）量子力学曲率解释中平面波的意义

量子力学概率解释中平面波 $|\psi|^2$ 的意义是指电子在空间任何地方出现的概率密度相同。在量子力学曲率解释中，平面波 $|\psi|^2$ 的意义是这样理解的：任何一个粒子（自在实体），比如电子，我们只有在相互作用中才能发现它，也就是只有在电子由静到动或由动到静的动量变化中才能发现它是什么形象。曲率解释中，因为 $|\psi|^2$ 与电子空间形象——曲率相关，对于自由电子，由于没有力作用于电子，因此电子的"空间形象"在自由飞行中无以表现。电子的动量，正是电子由静到动或由动到静，在相互作用中由动量差 $\Delta \boldsymbol{p}$ 形成的。这就是说，自由电子在时空中的形象只能是电子自由飞行前那一刻的形象。电子自由飞行时的"形象"（曲率）是不变的。由曲率和概率的对应关系，曲率不变，概率当然也相同。这就是 $|\psi|^2$ ＝常数的物理

意义。由于电子自由飞行时，没有力作用在电子上，没有反映电子形象的光学变化，我们不知道电子是什么样的，也不知道电子在哪里。这就是自由电子平面波的意义。我们要想知道电子在哪里，只有对其再次施予力的作用才行。这就是量子测量。

如果自由电子在讨论的问题中，其形可以忽略不计，电子波消失，电子回到宏观经典力学讨论的范畴，电子成了宏观的质点。

结合平面波归一化方法的讨论，我们发现对电子的描述，根据不同的环境，分别分成三个不同的层面：一是在讨论的问题中，电子的“形”不能忽略，而且“形”可变，本征态之间可以突变，电子在希尔伯特空间每一基矢上同时均有概率分布。这时粒子是虚的(鬼粒子)，波是实的，“物虚空实”是物理实在。此时，有独立的相干波源，态的叠加形成物理上的相干性，构成纯量子态。原子内部、无限深势阱、线性谐振子、双缝等中的电子就适合这一情形。二是量子测量中连续作用的介入，突变性消失，形成连续谱，不存在独立的相干波源，相干性消失，纯量子态变成混合态。三是在讨论的问题中“形”可以忽略，粒子自身只有粒子性而无波。这就是经典态。电子变成了宏观的质点，只有质点是物理实在，电子做轨道运动。这就是经典力学中的经典态。

第二节 规范场论中引进协变导数的物理实质及哲学思考

一般认为粒子与场的相互作用是通过引进规范场实现的。其实，对自由粒子做局域规范变换，粒子就已被自动置于场的相互作用之中了。当使自由粒子整体规范变换向局域规范变换过渡时，场的相互作用发生了从“无”到“有”的变化，规范不变性遭到了破坏。通过协变导数引进规范场，虽然体现了粒子与场的作用，但那是让粒子恢复“自由状态”的抵消作用。

一、经典电磁场规范变换的启示

经典电磁场理论中规范变换取以下数学形式[1]：

$$
\begin{aligned}
\boldsymbol{A}' &= \boldsymbol{A} + \nabla\alpha \\
\varphi' &= \varphi - \frac{\partial\alpha}{\partial t}
\end{aligned} \tag{7.19}
$$

式(7.19)中 $\boldsymbol{A}$ 为电磁场的矢势，φ 为电磁场的标势，α 是任意数学函数。

(一)局域规范变换

式(7.19)中若 $\alpha = \alpha(x,t)$ ，即 α 是时空点的函数，则有

$$\nabla\alpha \neq 0 \,,\ \frac{\partial\alpha}{\partial t} \neq 0$$

此时，由式(7.19)可知

$$\begin{cases} \boldsymbol{A}' \neq \boldsymbol{A} \\ \varphi' \neq \varphi \end{cases} \tag{7.20}$$

而规范变换中，有

$$\boldsymbol{E}' = \frac{\partial \boldsymbol{A}'}{\partial t} - \nabla\varphi' = \frac{\partial \boldsymbol{A}}{\partial t} - \nabla\varphi = \boldsymbol{E} \tag{7.21}$$

$$\boldsymbol{B}' = \nabla\times \boldsymbol{A}' = \nabla\times \boldsymbol{A} = \boldsymbol{B} \tag{7.22}$$

由式(7.22)和(7.20)知 $\boldsymbol{A} \neq 0$ 。因为 $\boldsymbol{A} = 0$ ，则有 $\boldsymbol{A}' = 0$ ，可得 $\boldsymbol{A}' = \boldsymbol{A}$ ，这与式(7.20)相违，故式(7.20)变为：

$$\begin{cases} \boldsymbol{A}' \neq \boldsymbol{A} \neq 0 \\ \varphi' \neq \varphi \neq 0 \end{cases} \tag{7.23}$$

式(7.23)表明局域规范变换对场 A 有非零值解要求。结合式(7.21)、(7.22)有：

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} \neq 0 \\ \boldsymbol{B}' = \boldsymbol{B} \neq 0 \end{cases} \tag{7.24}$$

式(7.24)表明，局域规范变换中，矢势 $\boldsymbol{A}$ 的变化，不影响场的相互作用，由于相互作用不变，因而也就不影响场中粒子运动状态的变化，局域规范不变性体现为场的相互作用的不变性或场中粒子运动状态的不变性。

故，对式(7.19)做局域规范变换($\alpha = \alpha(x,t)$)电磁场有唯一的非零值解。

(二)整体规范变换

式(7.19)中，若 α=常数，叫整体规范变换。则有

$$\nabla\alpha = 0$$

$$\frac{\partial\alpha}{\partial t} = 0$$

由式(7.19)有

$$\begin{cases} \boldsymbol{A}' = \boldsymbol{A} \\ \varphi' = \varphi \end{cases} \tag{7.25}$$

讨论:式(7.25)中若

① $\boldsymbol{A}' = \boldsymbol{A} \neq 0$, $\varphi' = \varphi \neq 0$,根据式(7.22)、(7.23)则有

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} \neq 0 \\ \boldsymbol{B}' = \boldsymbol{B} \neq 0 \end{cases} \tag{7.26}$$

② $\boldsymbol{A}' = \boldsymbol{A} = 0$, $\varphi' = \varphi = 0$,亦根据式(7.21)、(7.22)则有

$$\begin{cases} \boldsymbol{E}' = \boldsymbol{E} = 0 \\ \boldsymbol{B}' = \boldsymbol{B} = 0 \end{cases} \tag{7.27}$$

讨论(一)、(二)表明,方程(7.19)所描述的规范变换中,对整体规范变换(α =常数)而言,矢势 A 的规定不是唯一的非零值,多出了一个电磁场的零值解。

二、由动力学方程看物质波规范变换引进协变导数的物理实质

考虑一带电粒子在具有矢势 A 和标势 φ 的电磁场中运动,其薛定谔方程是

$$\begin{cases} i\hbar\dfrac{\partial\psi}{\partial t} = [\dfrac{(\hat{p}-qA)^2}{2m} + q\varphi]\psi \\ i\hbar\dfrac{\partial\psi'}{\partial t} = [\dfrac{(\hat{p}-qA')^2}{2m} + q\varphi']\psi' \end{cases} \tag{7.28}$$

式(7.28)中 $\boldsymbol{A}$ 与 $\boldsymbol{A}'$ 、φ 与 φ' 的变换关系由式(7.19)确定,物质波 ψ 与 ψ' 的变换关系是

$$\psi' = \exp(\frac{iq\alpha}{\hbar})\psi \tag{7.29}$$

式(7.29)是物质波的规范变换形式。式(7.29)中的 α 即为式(7.19)中的 α。[2]类似的有:

(一)$\alpha=\alpha(x,t)$,称物质波的局域规范变换

由第一节的讨论知,A 具有唯一的非零值解,规范变换保证场的

相互作用不变，带电粒子的运动状态不变。式(7.29)中 ψ' 、ψ 描述带电粒子在场中的同一变速运动状态，有规范不变性。

场具有唯一的非零解表明，只要对物质波 ψ 做局域规范变换，粒子就一定在场中，受到电磁力作用。

(二)α=常数，称物质波的整体规范变换

①由式(7.26)，$\boldsymbol{A}'=\boldsymbol{A}\neq 0$，$\boldsymbol{E}'=\boldsymbol{E}\neq 0$，则 ψ、ψ' 具有整体规范不变性，ψ、ψ' 描述带电粒子在场中的同一加速运动运动状态。

②由式(7.27)，$\boldsymbol{A}'=\boldsymbol{A}=0$，$\boldsymbol{E}'=\boldsymbol{E}=0$，则 ψ、ψ' 同样具有整体规范不变性，ψ、ψ' 描述带电粒子同一匀速运动状态，是自由粒子。

由物质波局域规范变换和整体规范变换的讨论可知，对物质波做局域规范变换，粒子必在场中，而对物质波做整体规范变换，粒子既可以在场中，也可以是自由粒子($\boldsymbol{A}=0$,$\boldsymbol{E}=0$)。

所以，当自由粒子整体规范变换向局域规范变换过渡时，场的相互作用发生了从"无"到"有"的变化。规范不变性遭到破坏，表明相互作用改变了粒子的运动状态，使得 ψ 与 ψ' 描述的不是粒子同一运动状态。通过协变导数引进规范场，抵消局域规范变换中粒子已有的场的作用，恢复粒子的"自由状态"，解决被破坏的规范不变性才是其真正的物理实质。可见，规范场的引入，虽然体现了粒子与场的作用，但那是让粒子恢复"自由状态"的抵消作用。上述物理实质的揭示，对认识规范变换的物理实质与哲学意义具有重要的启示作用。

三、德布罗意物质波及其相位变换的本质特征

(一)物质波相位的物理意义

如果狭义相对论是将运动物体的时空特征转化为建在其上坐标系的时空特征，那么，下述德布罗意推导物质波的过程，则是将坐标系的时空特征还原为运动物体自身时空特征的逆过程。

德布罗意推导物质波表达形式时，曾假设在惯性系 K′的原点有一静止质量为 m_0 的粒子，并且与静粒子对应有一个由振动引起的波源。[3]分析表明，应是由波长建构的"形内"虚质点的振动。

$$\psi = A\sin\omega_0 t_0 \tag{7.30}$$

其中

$$\omega_0 = 2\pi\nu_0 = \frac{m_0 c^2}{\hbar} \qquad \nu_0 = \frac{m_0 c^2}{h}$$

K'系是建在粒子上的坐标系，x_0, t_0 是 K'系的时空坐标；x, t 是 K 系的时空坐标；粒子运动前 K、K'系原点重合。并且 y_0、y 重合 x_0、x 重合。

现在假设粒子(或建在粒子上的坐标系 K')相对于 K 沿 x 轴正方向以速度 v 匀速运动，这相当于坐标系 K 沿坐标系 K'的 x_0 负方向匀速运动。

根据相对论，有

$$t_0 = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - v^2/c^2}} \tag{7.31}$$

将式(7.31)代入式(7.30)得：

$$\psi = A\sin\omega_0 \frac{t - \frac{vx}{c^2}}{\sqrt{1 - v^2/c^2}} \tag{7.32}$$

令
$$\omega = \frac{\omega_0}{\sqrt{1 - v^2/c^2}}, \nu = \frac{mc^2}{h}, v_p = \frac{c^2}{v}$$

则式(7.32)变为

$$\psi = A\sin\omega(t - \frac{x}{v_p}) \tag{7.33}$$

式(7.33)刚好表示 K 系中沿 x 轴正方向传播的自由粒子物质波。它是(7.14)式的变形，相当于把狭义相对论中的质量效应，变成了物质波的相位变化——频率 ν 的变化。如图 7.1。

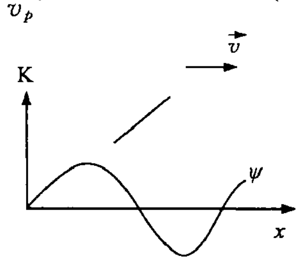


图 7.1　K 系中物质波示意图

物质波 ψ 的相速为

$$v_p = \frac{c^2}{v}$$

相速 v_p 是超光速的。

坐标系 K 中 x 轴上各点物质波 ψ 的相位在时刻 t 相对原点

$(x=0)$ 滞后的相角是

$$\alpha = \frac{\omega x}{v_p} = \frac{\omega v x}{c^2} \tag{7.34}$$

由式(7.34)可知。如果粒子不运动

$$v = 0$$

则

$$\alpha = 0$$

这表明，自由粒子物质波 ψ 的相位变化依赖于与物质波相联系的粒子的运动速度 v（或坐标系 K′的速度）。$v=0$，粒子不运动，就没有三维世界中物质波的观察效应，没有物质波的观察效应，当然更谈不上物质波相位的变化。$v\neq 0$，三维时空中有物质波的观察效应，但所对应的平面波只是“本体”通过“现象实体”给出的“影像”，类似于德布罗意的“导波”——相位波。曲率解释对“相位波”作出了说明。物质波是对粒子自身时空形象的描述。

（二）物质波初相的物理意义

图 7.1 中，K 系描述的自由粒子物质波 ψ，是粒子一离开原点 $x=0$ 时便开始记录的。初始条件是 $t=0$，$x=0$，物质波初始相位 $\alpha_0=0$。要使 K 系中描述的物质波的初相不为零，可在粒子运动了一段时间后，比如，$x=x_0$ 之后开始记录。设被记录的物质波为 ψ'，则物质波式(7.33)中的位置变量 x 应为

$$x = x_0 + x'$$

于是式(7.33)变为

$$\psi' = A\sin\left[\omega t - \frac{\omega(x_0+x')}{v_p}\right] = A\sin\left[-\frac{\omega v x_0}{c^2} + \omega t - \frac{\omega v x'}{c^2}\right] \tag{7.35}$$

注意：这里的 x' 仍然是 K 系的时空标度。当 $x_0=0$ 时，式(7.35)回到(7.33)。

令

$$\alpha_0 = \frac{\omega v x_0}{c^2} \tag{7.36}$$

且将 x' 仍用 x 标记，则式(7.35)变为

$$\psi' = A\sin\left[-\alpha_0 + \omega t - \frac{\omega v x}{c^2}\right] \tag{7.37}$$

α_0 即为物质波的初相。它包含有粒子运动速度因子，有特定的数学结构和物理含义。式(7.37)即为 K 系中一个初相不为零的自由粒子物质波波函数。与式(7.33)描述的物质波相比，它只是在同一坐标系中，把描述同一物质波运动的空间起点往后平移了一段距离，数学上是坐标系平移，物理上类似交流电初始相位中转子的初始方位。如图 7.2。

图 7.2 中，物质波 ψ、ψ' 描述的显然是同一参照系中粒子的同一波动状态。但记录物质波的空间起点不同，即初相不同。ψ、ψ' 描述的是自由粒子的同一运动状态。这正是规范变换的要求。

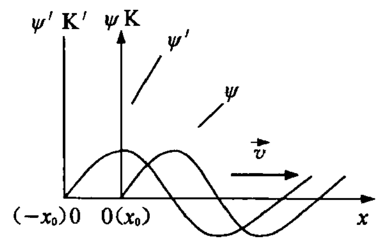


图 7.2 初相不为零的物质波示意图

物质波初相与记时起点的关系正好体现了狭义相对论时间变换与位置 x 相关的物理实质。记时位置的不同，t_0、t 的时差不同，初相当然不同。

(三)德布罗意自由粒子物质波规范变换的物理实质

①整体规范变换。

我们把式(7.33)和式(7.37)表示的波函数写成指数函数形式：

$$\psi = Ae^{i\alpha}$$

其中
$$\alpha = \omega t - \frac{\omega v x}{c^2}$$

令
$$\alpha' = -\frac{\omega v x_0}{c^2} + \omega t - \frac{\omega v x}{c^2}$$
$$= -\alpha_0 + \alpha$$

所以
$$\psi' = Ae^{i\alpha'}$$
$$= Ae^{i(-\alpha_0+\alpha)}$$
$$= Ae^{i\alpha}e^{-i\alpha_0}$$

故有
$$\psi' = \psi \cdot e^{-i\alpha_0} \tag{7.38}$$

式(7.38)中，初始相位 α_0 = 常数，他具有阿贝尔和非阿贝尔整体规范变换形式。从 α_0 特定的物理含义和数学结构知，α_0 = 常数，意味着与物质波相联系的粒子的运动速度 v = 常数 $\neq 0$，是自由粒子，做

匀速运动，且记录物质波的初始位置 $x = x_0$ ，式(7.38)就是德布罗物质波自由粒子整体规范变换形式。

由狭义相对论，$m_0c^2 = \mathrm{h}\nu_0$、$mc^2 = \mathrm{h}\nu, m = m_0/\sqrt{1-v^2/c^2}$ ，质量的增加转化为物质波频率、相位的变化表明，物质波的整体规范变换与运动粒子引力势的全空间统一增加，有着内在的统一联系。

②局域规范变换。

在初相

$$\alpha_o = \frac{\omega v x_0}{c^2} \tag{7.39}$$

中，如果 $v = v(x,t)$ ，即 v 是时空点的函数，则有 $\alpha_0 = \alpha_0(x,t)$ ，表明粒子处在力场之中，做加速运动。

将

$$\alpha_0 = \alpha_0(x,t)$$

代入式(7.38)有

$$\psi' = \psi \cdot e^{-i\alpha_0(x,t)} \tag{7.40}$$

式(7.40)具有阿贝尔和非阿贝尔局域规范变换形式。对自由粒子物质波做局域规范变换表明，只要对自由粒子物质波做局域规范变换，粒子就已置于力场之中。这再次证明，粒子与场的作用，不是通过协变导数引进规范场时才产生的。规范场的引进，尽管体现了粒子与场的作用，但那是让粒子恢复自由状态，实现规范不变性引进的抵消作用。[4]

粒子的加速运动与物质波的局域变换相联系表明，局域规范变换与运动粒子质量局域变化引起引力势局域变化相关。

四、杨—米尔斯规范场引进协变导数的物理实质

(一)整体规范变换

设 ψ 为自由粒子的波函数，并对 ψ 和 $\bar{\psi}$ 做整体规范变换，其中 $\alpha =$ 常数

$$\begin{aligned}
\psi &\to \psi' = e^{-i\alpha}\psi \\
\bar{\psi} &\to \bar{\psi}' = \bar{\psi}e^{i\alpha} \\
\partial_\mu\psi &\to \partial_\mu\psi' = e^{-i\alpha}\partial_\mu\psi
\end{aligned} \tag{7.41}$$

$\alpha =$ 常数，根据对德布罗意自由粒子物质波的分析。则有 $\partial_\mu\alpha = \partial_\mu v = 0$ ，对应自由粒子的匀速运动，且有流和荷的守恒。

构造自由场的拉格朗日密度

$$\mathscr{L}=\overline{\psi}\,(\mathrm{i}r^{\mu}\partial_{\mu}-m)\,\psi \tag{7.42}$$

将式(7.41)中的 $\overline{\psi}$、ψ、$\partial_{\mu}\psi$、$\overline{\psi'}$、ψ'、$\partial_{\mu}\psi'$ 代入方程(7.42)即可得到

$$\mathscr{L}_{\psi}\rightarrow\mathscr{L}_{\psi'}=\mathscr{L}_{\psi}$$

将 $\mathscr{L}_{\psi}$ 和 $\mathscr{L}_{\psi'}$ 代入拉格朗日方程

$$\partial\mathscr{L}/\partial\psi-\partial_{\mu}(\partial\mathscr{L}/\partial\partial_{\mu}\psi)=0 \tag{7.43}$$

即可得到不变形式的狄拉克方程

$$\begin{aligned}&(ir^{\mu}\partial_{\mu}-m)\psi=0 && \text{(a)}\\&(ir^{\mu}\partial_{\mu}-m)\psi'=0 && \text{(b)}\end{aligned} \tag{7.44}$$

(二)局域规范变换

式(7.41)中,若 $\alpha=\alpha(x,t)$,即所转相角是时空坐标 x,t 的函数。此时,必有 $v=v(x,t)$,粒子被置于场中做加速运动。对自由粒子的场量及其导数做局域规范变换:

$$\begin{aligned}&\psi\rightarrow\psi'=e^{-i\alpha(x,t)}\psi && \text{(a)}\\&\overline{\psi}\rightarrow\overline{\psi'}=e^{i\alpha(x,t)}\,\overline{\psi} && \text{(b)}\\&\partial_{\mu}\psi\rightarrow\partial_{\mu}\psi'=\partial_{\mu}[e^{-i\alpha(x,t)}\psi]\\&\qquad=e^{-i\alpha(x,t)}\partial_{\mu}\psi-i\partial_{\mu}\alpha(x,t)e^{-i\alpha(x,t)}\psi && \text{(c)}\\&\qquad\neq e^{-i\alpha(x,t)}\partial_{\mu}\psi\end{aligned} \tag{7.45}$$

将式(7.45)代入拉格朗日密度式(7.42),有

$$\mathscr{L}_{\psi}\rightarrow\mathscr{L}_{\psi'}\neq\mathscr{L}_{\psi} \tag{7.46}$$

将 $\mathscr{L}_{\psi}$、$\mathscr{L}_{\psi'}$ 代入拉格朗日方程,显然不能保证拉格朗日方程和狄拉克方程的形式不变。[5]

若 $\partial_{\mu}\alpha(x,t)=\partial_{\mu}v(x,t)=a_{\mu}=0$,则粒子做匀速运动,式(7.45)中($c$)式第二项消失,这就是自由粒子整体规范变换。场量 ψ、$\partial_{\mu}\psi$ 及 $\mathscr{L}$ 具有规范不变性。可见 $\alpha=\alpha(x,t)$ 时规范不变性的破坏,完全是由于 $\partial_{\mu}\alpha(x,t)=\partial_{\mu}v(x,t)=a_{\mu}\neq0$,即已将自由粒子置于场中,相互作用从"无"到"有"造成的。电荷的加速运动,使流和荷的守恒遭到了破坏,也使拉格朗日方程和狄拉克方程的不变性遭到了破坏。要保证拉格朗日方程和狄拉克方程的不变性,必须引进作用相反的作用力,抵消原场对粒子的作用,使总作用力为零,以保证电荷的自由运动状态,实现规范不变性。引进协变导数

$$\partial_{\mu}\rightarrow D_{\mu}=\partial_{\mu}-ieA_{\mu} \tag{7.47}$$

就可以达到这一目的。式中 A_μ 即为引进的规范场。规范场的引入，虽然体现了带电粒子与电磁场的作用，但那是一种抵消作用，过去人们对这一物理机制似乎认识不足。引入协变导数后拉格朗日密度为：

$$\mathscr{L}=\bar{\psi}(ir^\mu D_\mu-m)\psi \tag{7.48}$$

A_μ 是电磁场，则粒子的受力就是电磁力。带电粒子与电磁场相互作用的总拉格朗日密度可写成

$$\mathscr{L}=\mathscr{L}_{\psi+\mathrm{i}}+\mathscr{L}_{\mathrm{A}}=\mathscr{L}_{\psi'+\mathrm{i}}+\mathscr{L}_{\mathrm{A}'} \tag{7.49}$$

将式(7.49)代入拉格朗日方程，即可得到形式不变的狄拉克方程：

$$(ir^\mu D_\mu-m)\psi=0 \tag{7.50}$$

我们看到，物理系统内部空间的对称性及拉格朗日密度不变性预示对应守恒流 j_μ^i 和守恒荷 Q^i 所揭示的物理本质：流和荷的守恒刚好对应载荷粒子的匀速运动，规范不变性的破坏，意味着流、荷守恒的破坏，即粒子匀速运动的状态的破坏，这是自由粒子整体规范变换过渡到局域规范变换的实质。

讨论：

一般认为规范变换中的内部空间的转动与外部空间没有关系。但本节的讨论表明：

①当自由粒子物质波由整体规范变换向局域规范变换过渡时，建在粒子上的坐标系 K′也由匀速运动过渡到加速运动。通过协变导数，引进规范场，可以恢复粒子的自由运动状态。

②考虑加速运动的坐标系中有等效“引力场”，而“引力场”对应非均匀时空，那么，自由粒子整体规范变换→局域规范变换(电磁场出现)→规范不变性的破坏，与建在自由粒子之上 K′系由均匀时空(匀速运动)→非均匀时空(非匀速运动)(引力场出现)→时空均匀性的破坏就形成了有机的内在联系。引进规范场恢复粒子的匀速运动实现规范不变性，与引进反向引力场实现局部平直时空在思维方法上就是等价的。自由粒子整体规范变换与狭义相对论，局域规范变换与引力场有着深刻的内在联系。上述讨论包含有将粒子自身的时空特征转换成坐标系的时空属性的复归。

③本文的讨论可能对认识真空对称性破缺的物理意义和哲学意义有重要作用。

由此我们提出如下问题：带电自由粒子由整体规范变换过渡到局域规范变换，通过协变导数引进电磁场可实现规范不变性，若是非带电自由粒子，由整体规范变换到局域规范变换，通过协变导数引进引力场又将如何？物质波有无规范不变性？引力场与粒子运动速度的连续变化相关，这是否是引力场不能量子化的原因之一？

参考文献

[1] 俞光大. 电工基础(下册)[M]. 北京：高等教育出版社，1966：185.

[2] 时庆云. 量子力学[M]. 北京：北京理工大学出版社，1993：157-158.

[3] 何祚庥. 量子力学的丰碑[M]. 桂林：广西师范大学出版社，1994：233-242.

[4] 赵国求，桂起权，等. 物理学的新神曲[M]. 武汉：武汉出版社，2004：329.

[5] 胡瑶光. 规范场论[M]. 上海：华东师范大学出版社，1984：45-51.

Chapter 8
The Fourth Edition of the Theory of Structure Reality

Now we can make relevant conclusion of the theoretical foundation of curvature interpretation of quantum mechanics.

8.1 Experimental Appearance, Physical Model and Quantum Measurement

Point particle model is the root cause of the occurrence of many contradictions in logics in interpretation system of present quantum mechanics.[1][2] The necessary approach to eliminate these contradictions in logics is to revise point particle model in quantum mechanics. When curvature model passes through matter wave wavelength, the "form"($r=\lambda/2\pi$)of microscopic object defined and constructed by phase circle cannot be ignored in the discussion of the issues about atom. Mass point abstract principle in classical mechanics does not suit atomic world or cannot be indiscriminately copied.

To transform quantum appearance in atom into research target of classical mechanics in macroscopic experience, one must change discontinuous distribution of energy into continuous distribution, and discontinuous effect into continuous effect. That is the main mission of quantum measurement.

8.1.1 The Establishment of Physical Model of Wave Particle Duality in Quantum Mechanics

Mass point is physical reality described by Newtonian mechanics and theory of relativistic mechanics. All the energy, momentum, location and time possessed by object are given to mass point of no geometric size. If certain marginal conditions are given, if motional equation of mass point is established, the past, the present and the future of motional object can be known. Determinism is the common property of Newtonian mechanics and theory of relativistic mechanics. In macro low speed and macro high speed, Newtonian mechanics and theory of relativistic mechanics discussed physical issues with mass-point model, which suits well to experimental appearance.

In present-day quantum mechanics, mass-point model is still used. However, things become very complex when mathematical pattern of quantum mechanics and physical essence of mathematical pattern are to be understood and experimental appearance is compared with it. There are at least about seven to eight more popular quantum mechanics interpretations; each interpretation, through a physical model, tries to establish intrinsic connection between described physical reality in quantum mechanics, some of which succeeded, but some ended with unhappy regret.

Throughout the history, in the discussion of specific issues of atom and the interpretation of experimental appearance, Ernest Rutherford put forward the planet model of the solar system on the basis of point particle; Niels Bohr put forward energy level transition model of atomic electron orbit; Albert Einstein advanced light quantum model; Werner Karl Heisenberg brought forward observable matrix model; Erwin Schrödinger suggested wave packet model; Louis de Broglie made guided wave and double solutions model; David Bohm put forward quantum potential model; and quantum

field theory constructed vacuum excited state model.

The key to the establishment of the above models is to seek reasonable interpretation for physical mechanism that contains wave and particle in itself and its channel of production, in microscopic world. Ernest Rutherford model, constructed on point particle model of classical mechanics, has to be given up because it cannot explain the stability of atom and has no relation with vibration appearance. Niels Bohr energy level transition model made great progress, compared to Ernest Rutherford model. However, although it solved the problem of atom stability, it is not so satisfactory, for its four quantum numbers is only an external hypothesis, and corpuscular property of microscopic object and undulatory property can only be explained with complementary principle. Between 1905 and 1916, Albert Einstein established the relation between light energy and frequency, and between momentum and wavelength: $E=h\nu$ and $p = h/\lambda$, which only provided correspondence of particle and wave in form, not to say revealing the intrinsic relation of the two in nature. Although Werner Karl Heisenberg matrix model well summarized the relation between atom appearances, it gave microscopic object inherent uncertainty. So, although he provided mechanical basis for M. Born probability wave, he was strongly opposed by Albert Einstein. Erwin Schrödinger constructed wave equation of micro particle, and suggested wave packet of factual particle, which was not extensively accepted because wave packet diffusion was denied by experiment. Broglie guided wave and double solution model developed very slowly and had no immediate advantage in a short period of time because of the difficulties in mathematics. Von Neumann was the promoter of the theory of Copenhagen School, whose construction of axiomatized interpretation system increased people's cognition of wave particle duality greatly. However, Von Neumann collapse of wave packet difficulty was inconceivable. Decoherence interpretation attempted

to solve this problem, but its theoretical logical structure still left much to be gained. David Bohm quantum potential model was the product of typical thinking mode which believed micro particle was equal to macro particle; its physical essence of quantum potential was not clear and definite, and it was reproached by some physicists for it was doubtful if there were circulative demonstration between wave function and quantum potential. Presently, all are look to quantum field theory, but its problem is that the existence of substance status of point particle still block the way to the solution of the difficulties in two-slit experiment.

In the above-mentioned models, particle is fundamental for the models of Ernest Rutherford, Niels Bohr, Werner Karl Heisenberg, and David Bohm; while on the surface, wave is fundamental for Erwin Schrödinger and Louis de Broglie models, but deep in its ideology, there is still the background of point particle; in quantum field theory, wave is fundamental: particle is stirred up from vacuum field and there is new understanding of co-existence of wave and particle. However, no matter in which model, the two separated concepts (wave and particle) are brought together into the same model.

To construct a truly united wave-particle model is necessary for the development of quantum mechanics and for the cognition of physical essence of wave-particle unity of microscopic object. In Wuhan Scientific Community initiated by Prof. Gui Qiquan, in their analysis of the mathematical structure of particular wave function of micro particle and the properties of its internal space phase circle, Zhao Guoqiu suggests curvature model of micro particle and names the quantum mechanics interpretation thus constructed curvature interpretation of quantum mechanics.

8.1.2 Curvature interpretation of Quantum Mechanics

The basic points of curvature interpretation of quantum mechanics is:[3]

① Acknowledge that microscopic objects (electron and the like) are not mass point, wave function is the description of self space-time characteristics;

② Define and construct the "form structure" of electron and other microscopic objects in internal space through Broglie matter wave wavelength ($\lambda_n/2\pi = r_n$ radius of curvature of phase circle);

③ Eigenstate is integrated by reference curvature R_n and function $G_n(x)$ given by "form structure"

$$R_n = 1/r_n, \quad r_n = \lambda_n/2\pi$$

In hydrogen atom, λ_n is Broglie static wave wavelength of energy level n. Eigenstate wave function can be written to:

$$\psi_n = R_n G_n(x) \qquad (8.1)$$

The superposition pattern of eigenstate is

$$\psi = \sum_{n=1}^{n} R_n G_n(x) \qquad (8.2)$$

Equations (8.1) and (8.2) can both be obtained in existing wave function amplitude of quantum mechanics through abstracting common factor R_n. Existing mathematical pattern of quantum mechanics does not change but its physical connotation is explicit.

④ Curvature and probability can be interchanged. When bending degree of curvature is big, probability is big; bending degree of curvature is small and then probability is small; bending degree of curvature becomes zero and probability is zero.

Correspondence of R_n experimental appearance is: bending degree of curvature is big and "image" is small, so the probability to find point electron in "image" is big, transition frequency of electron is high and light intensity is strong; however, if bending degree of curvature is small, "image" is big, so the probability to find point electron in "image" is small, transition frequency of electron is low and light intensity is weak. If "image" is infinite (far away from atomic nucleus), bending degree of curvature is zero, probability to find point electron in "image" is zero and light intensity is

zero, either.

Curvature interpretation may contain probability interpretation and corresponds well to experimental appearance.

⑤ Matter wave is curvature wave (but with probability attributes). Curvature bending degree expresses corpuscular property, curvature change exhibits undulatory property. Curvature wave organically unifies corpuscular property and undulatory property of microscopic object in the same model, thus avoiding the imperfection that wave-particle concept is separated in all the above-mentioned models and the loss of "image" of microscopic object in point model and reducing mathematical wave into physical wave.

In the "internal space" constructed with object "image", energy and momentum are given to "space"; wave is real and particle is virtual; virtual particle has no motional track. In "external space", energy and momentum are given to point particle; particle is real and wave is virtual (probability wave); real particle has motional track. Quantum measurement is a process of eliminating discontinuous change of energy through involvement of continuous effect, and transforming substance wave and virtual particle of internal space into real particle and virtual wave (probability wave).

8.1.3 Curvature Wave Case Study [4]

8.1.3.1 Hydrogen atom

With regard to hydrogen atom, wave function of curvature wave is derived from the original wave function:

$$\begin{aligned} R(r) &= (1/na_0)2B_0e^{-\frac{\rho}{2}}\rho^l \angle_{n+l}^{2l+1}(\rho) \\ &= R_n 2B_0 e^{-R_n r}(2R_n r)^l \angle_{n+l}^{2l+1}(2R_n r) \\ &= R_n G(r) \end{aligned} \tag{8.3}$$

in equation (8.3), $R_n = 1/na_0$, $na_0 = r_n = \lambda_n/2\pi = \lambda\!\!\!^{-}_n$, λ_n is Broglie static wave wavelength of electron in hydrogen atom. R_n is electron's reference curvature at No. n energy level, through which the basic

"image" of electron can be defined and constructed.

Electron wave in hydrogen atom is curvature wave with reference curvature R_n as amplitude. Curvature is in direct ratio with electron transition probability, probability is interchangeable with curvature and curvature contains probability attribute.

From amplitude of wave function of any other matter wave, we can separate reference curvature radius r_n defined by matter wave wavelength λ_n or curvature R_n. so, curvature interpretation has its universality.

8.1.3.2 Arthur Holly Compton matter wave

It is reasonable that Compton wavelength $\lambda\!\!\!^{-}_0$ and $\lambda\!\!\!^{-}_c$ are usually used to represent particle measurement.

A. Static Compton matter wave ψ_0

$$\psi_0 = a_0 \exp\left[\frac{i}{\hbar}(p_0 \cdot r - E_0 t)\right] \tag{8.4}$$

In equation (8.4), $p_0 = m_0 c, E_0 = m_0 c^2, m_0$ is static mass of particle, $a_0 = \frac{1}{r_0} = \frac{1}{\lambda\!\!\!^{-}_0} = \frac{1}{\hbar/m_0 c} = \frac{m_0 c}{\hbar} = R_0$. Therefore, Compton static matter wave is curvature wave. Because $p_0 \cdot r = 0$, this wave is observable in reality. (See appendix 2)

B. Dynamic Compton matter wave ψ_c

$$\psi_c = a_c \exp\left[\frac{i}{\hbar}(p_c \cdot r - E_c t)\right] \tag{8.5}$$

In equation (8.5), $p_c = mc, E_c = mc^2, m$ is motional mass.

$$a_c = \frac{1}{r_c} = \frac{1}{\lambda\!\!\!^{-}_c} = \frac{1}{\hbar/mc} = R_c$$

So, Compton dynamic matter wave is also curvature wave. Because $p_c \cdot r \neq 0$, it has component in three-dimensioned space and the wave is observable.

R_0 and R_c indicate the structure of electron in different conditions. Neutron and proton Hoffstadt measured through experiment and distributing radius of electrical charge of electron the others measured in experiment suited very well to the result of calculation

in R_0 and R_c. [5]

8.1.4 Describing Object of Erwin Schrödinger Equation

8.1.4.1 Classical mechanical wave superposition

If y_1、$y_2 \cdots y_n$ is the solution of linear wave equation, then, $y = y_1 + y_2 + \cdots + y_n = \sum_{n=1}^{n} y_n$ is also its solution. Total motional effect of mass point caused by sub-wave y_1、$y_2 \cdots y_n$ passing the same point of medium is equal to the totality of motional effect caused by each sub-wave individually affecting on the same mass point. Because classical wave equation is partially differential equation of space-time, effect of each sub-wave on mass point is regarded as continuous, and energy change of mass point in motion is also continuous.

In order to have better understanding of quantum fluctuation, brief analysis can be made on classical vibration as follows:

① If there is no fixed phase difference between sub-waves y_1、$y_2 \cdots y_n$, the point will show resonant appearance affected by sub-wave gathering on certain point. See diagram 8.1.

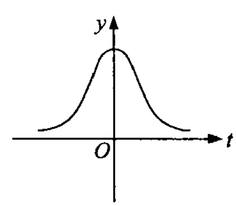


Diagram 8.1 Resonance peak image (wave packet) formed by wave superposition

② If there is fixed phase difference between sub-waves y_1、$y_2 \cdots y_n$, transmission and superposition of wave may cause some point vibration to increase all along to different space-time point in medium and some point vibration to decrease all along, and that is wave interference. Two-slit interference is a case in point.

Necessary condition for wave interference is fixed phase difference between independent interference wave sources and wave source.

③ Resonance curve of any one mass point can be spread in

Fourier approach, and the resolved sub-wave comes from the different vibration mode of the same mass point. Vibration of mass point becomes common wave source of particular sub-wave. Obviously, different sub-waves in classical mechanics may come to one point and form resonance image of mass point. Conversely, the vibration of this mass point can also be regarded as a wave source and be further decomposed into many independent, energy-continuous and effect-continuous sub-waves, between which there is no coherence.

In classical mechanics, in fluctuation image formed from probability distribution of mass point, mass point is real (mass point obtains energy and momentum), wave is virtual and wave is only a kind of distribution function of mass point in space-time sequence (phase wave).

8.1.4.2 Superposition of wave function in quantum mechanics

In quantum mechanics, Erwin Schrödinger wave equation is obtained from classical analogy. If ψ_1、$\psi_2 \cdots \psi_n$ is solution of linear wave equation, $\psi = \psi_1 + \psi_2 + \cdots + \psi_n = \sum_{n=1}^{n} \psi_n$ is also solution of the equation. According to the condition of classical analogy, energy and effect of sub-wave (eigenstate) between ψ_1、$\psi_2 \cdots\cdots \psi_n$ is also in continuous change. Therefore, Erwin Schrödinger believed that his equation did not need the concept of quantum transition and the like. Like radio wave, electron wave possesses substance property and is density distribution of mass or electrical charge. Electronic corpuscular property is measured with wave packet. Wave scattering is denied by experiment, and wave packet model is not widely accepted. Besides, to apply Schrödinger equation to specific physical object (like hydrogen atom), it must be assumed that, there will be no solution that agrees with physical reality until undetermined coefficient (energy) can change discontinuously, which indicates that, atomic electron transition concept can not be ignored.

In atom, energy changes suddenly between various sub-waves (eigenstates) corresponding to the same electron, effect is discontinuous and quantum of action exists! Between two energy levels: $E_2 - E_1 = h\nu$, because $h\nu$ unchangeable property, it indicates that there is fixed phase difference between two eigenstates that correspond to each other, so there is coherence between eigenstates.

Take two energy levels as an example:

$$|\psi|^2 = |\psi_1 + \psi_2|^2 = |\psi_1|^2 + |\psi_2|^2 + \psi_1{}^* \psi_2 + \psi_2{}^* \psi_1$$

$\psi_1{}^* \psi_2 + \psi_2{}^* \psi_1$ is interference item, ψ is pure state wave function of quantum mechanics.

In atom, because of the existence of independent interference wave sources, various sub-wave (eigenstate) corresponding to electron cannot form single resonance peak of electron but relative interference image. See diagram 8. 2

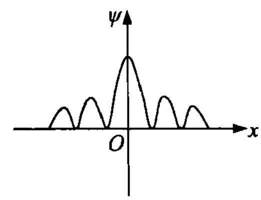


Diagram 8. 2 two energy levels interference image of electron wave

Even though "general image" of atomic electron presents discreteness, discontinuity of electron energy and effect between energy levels may reduce electron simultaneously to correspond to various independent and parallel sub-wave wave source with coherent properties. A particle possesses scattering "general image" and may appear in wave coherence, and wave obtains energy and momentum. Obviously, wave has substance properties; then, what is scattering "general image"? Macro point particle is impossible. Compared with macro experience, particle "concentration configuration" is a mere virtual form. The above mentioned curvature model just reflects this essential characteristic of atomic microscopic object. One description level of Erwin Schrödinger equation is expressed here.

On atom external (above zero potential surface), electronic energy can be in continuous distribution, solution superposition is

changed to:

$$\psi = \int \varphi(x)\mathrm{d}x$$

$\varphi(x)$ is continuous spectrum eigenstate, between which fixed phase difference disappears and there is no coherence. Particle may resume its substance "concentration configuration". ψ is just the wave packet constructed by continuous spectrum. When "shape" is neglected, what Erwin Schrödinger wave packet represents is classical particle possessing local "general image"——motional pattern of mass point. Because of the disappearance of coherence, ψ reveals a mixed state. This is another level in Erwin Schrödinger equation, in which, after the "shape" of the particle is neglected, particle possesses substance properties and wave is in virtual state. Wave is probability distribution function of substance particle. It is the evidence that Erwin Schrödinger equation can be used for classical analogy.

Microscopic objects, whether pure quantum state possessing scattering "general image" attributes or mixed state with local "general image" characteristics, are reversible in their individual evolution in Erwin Schrödinger equation. However, evolution from pure state to mixed state is not reversible, because it is involved from atom internal to external, from energy discontinuous distribution (Summation: expressed with $\sum$ in mathematics) to energy continuous distribution (Summation: expressed with $\int$ in mathematics), from discontinuous to continuous interaction, from electron substance wave and virtual particle to real particle and virtual wave. Things leap forward from quantitative change to qualitative change. The interference of continuous effect in quantum measurement and energy-eliminated discontinuous distribution can just realize this leap from quantitative change to qualitative change.[6]

8.1.5 Essence of Quantum Measurement

Now we can give new interpretation to the essence of quantum measurement:

So-called quantum measurement, in nature, is to exert a similar continuous interaction on tested system (S) through measuring instrument (or other outside environment) so that energy state of tested system (S) turns from discontinuous change to continuous change. Thus, both catastrophic independent interference wave sources and fixed phase difference between sub-waves can be eliminated, so that coherent conditions of tested system are completely lost. In experimental appearance, multi-peak coherence changes to single-peak resonant wave packet.

Instrument (M) (or environment) provides a continuous interaction for system (S) and changes pure state into mixed state, which does not mean to cut apart atom infinitely. When orderly quantum transition becomes out of order, absolute value of momentum does not change but its direction changes. Considering from the whole, energy and discontinuity of interaction disappears similarly. It definitely indicates the increase of quantum entropy, so it is reasonable that the increase of quantum entropy and quantum measurement is connected. According to the new quantum measurement mechanism, the counter process of continuous action to non-continuous action may also exist. But the counter process does not apply to auto-decoherent macro measurement instrument.

Niels Bohr believed that quantum measurement is that instrument exerts a kind of uncontrollable interaction on micro tested system and produces a random phase angle on corresponding eigenstate, thus coherence of tested system disappears. In fact, now we see that it is not "uncontrollable interaction" but a continuous effect that instrument provides. So-called random angle results from sudden change of energy to continuous change and elimination

of fixed phase difference. The two conditions that tested system produces coherence is lost in interaction between system and instrument, so it is natural that coherence disappears.

If it is considered that Niels Bohr measurement theory indicates that the effect of macro measuring instrument on micro tested system reduces micro tested system from pure state to mixed state, then, Von Neumann thinking modes is just opposite to that of Niels Bohr. He first assumes macro instrument as pure quantum state, and interaction that is aroused from pure instrument and pure system will not change system state but measuring instrument state. When instrument is decoherent, tested system state may be "read" from instrument state. We have made analysis on the theory of quantum decoherence based on Von Neumann theory (Section 3, Chapter 6): if instrument may automatically becomes decoherent instantly, then entangled state

$$\psi = \sum_n C_n |n\rangle |e\rangle \tag{8.6}$$

will have mathematical sense but no physical sense. Because instrument automatically becomes decoherent, in real physical measurement, it is impossible for pure instrument to exist in equation (8.6). It will be logically incompatible in theoretical system of decoherence in quantum mechanics. [7] Therefore, the further popularization of theory of decoherence will be unnecessary.

If it is considered that quantum measurement is a continuous effect of instrument on tested system to reduce tested system to change from pure state to mixed state, then, quantum entanglement can be understood as entanglement of pre-state and post state of tested system in measurement itself. [8] It is this self-entanglement that realizes transition from energy catastrophe to continuous transformation, thus system coherence disappears. Obviously, Von Neumann hypothesis of pure quantum state on instrument will also be unnecessary.

8.2 Theory of Interactive construction Reality—Fourth Edition of Theory of Structure Reality

The theory of interactive construction reality belongs to structure reality theory. Interaction is the cause of structure mechanics, curvature model is individualization of theoretical structure of quantum mechanics. "Substance of appearance" and "curvature model" are links in coordination and unity of present contradiction in scientific philosophy and quantum mechanics.

8.2.1 Realism and Counter Realism in Scientific Philosophy

Realists and counter-realists have different answers to the question what scientific terms indicate, whether microscopic object such as electron, really exist or not. Realists believe "things" which are indicated by scientific terms are real existence: like electron, it really exists although invisible. While counter-realists deny or doubt about the objective reality of microscopic object in scientific theory, as in the case of electron: they deny or doubt whether electron is in real existence.

Basic theoretical evidence for realists to believe that microscopic objects as electron in scientific theory really exist is as follows: [9]

① Theoretical terms cannot be distinguished from observational terms: although what theoretical terms indicate is invisible today, its visibility will be provided with the development of science. For example, cell was once invisible, but it can be seen with the help of microscope. In principle, there is nothing that cannot be observed in the world, and what is theoretical term today may become observational term tomorrow. Theoretical terms indicate objective reality.

② The best explanative deduction. G. Harman believed that if

a theory could better explain experiential evidence than its competitor, it should be superior and we would have more confidence in it.

③ Micro structure really exists, with which scientific theories often explain appearance. Wilflid Sellars believed that it was necessary for scientists to believe the existence of these unobserved micro structure, for example, quark that construçts atom, "Cooper electron pair" which is introduced to the theory of superconductivity. It is difficult for scientists to doubt the existence of these invisible "quark" and "electron pair" and only believe observable appearance produced by them.

④ Non-miracle demonstration. If we do not believe theory as real, then, we can only acknowledge that the success of modern science is only a "miracle". "Miracle" refers to occurrence that is not reasonable and science should not be unreasonable. Theory of reality is the only philosophy in which science does not become a "miracle".

The basis that opponents of scientific reality deny the real existence of microscopic objects, such as electron, in scientific theory is:

① Certain given experiential evidences are correspondent to many logically compatible theories. If what theoretical terms indicate is "real", whichever theoretical reference is "real"? One should know that, any theory is based on the same experiential evidence! So, opponents of reality theory draw their conclusion: experiential evidence cannot determine whether scientific theory is true or false, which is called "inadequate determinism".

② After science revolution, there is irreductive pattern between old and new theoretical modes. Noumenon concept in the original scientific theory is not acknowledged in the new one. Phlogiston and ether are examples. Thomas Kuhn said: "I haven't seen (in replacement of theories) the continuity of development of noumenon theory". This is "noumenon discontinuity". [10]

If there is no revolution in science, "noumenon" is "not fully

determined"; after science revolution, "noumenon" is completely discontinuous. Then, such "noumenon" still exists? Previous theoretical terms do not refer to anything, so present theoretical terms will not refer to anything in the future. Theoretical reference is not real.

Van Frassen, representative of present counter-realists, criticized reality theory. [11] He said, Maxwell only proved that the difference between observation and unobservability was indistinct and ambiguous, and he did not clearly point out that it was undistinguished, and that his observation of microscopic object was indirect; the best explanative deduction is only psychological hypothesis, and the theory that can better explain experimental evidence is only proper in experience; not all scientific phenomena need further interpretation, so behind probability wave, "hidden parameter" support is not needed; the reason for the success of modern science lies in the fact that we have washed out defeated theories. All these indicate that, science does not discover truth but that it is only suitable to experience.

We think that Van Frassen's version that new theory "cleans out" old one is not so accurate. Reasonable expression should be: new theory "substituting" the old one. "Substitution" contains two shades of meaning: ① "substitute" the wrong with the correct, ② "substitute" the imperfect with the perfect. Development of relativistic mechanics on Newtonian mechanics does not mean that Newtonian mechanics has died out but that the former can explain more natural phenomena, answer more "whys", and put forward more predictions than Newtonian mechanics. New theories behave "better" than the old ones. Science revolution often reflects the deep-going gradation of human cognition and its intensification.

Based on interactive construction reality, the human direct experience is generally the product of direct physioconstruction. The human initial cognition of the nature is only appearance. What is behind appearance should be constructed by theoretic structure and

logic reasoning. The "thing" thus constructed is only "substance of appearance" or "physical noumenon". It is the presence of reality in specific interaction, including observation (theoretic structure). "Substance of appearance" (physical noumenon) is real and can be reverted to appearance through logic inversion, thus acceptable in experience.

counter-realists denied the existence of the things theoretic terms indicate, the cause of which may be from their knowledge of electron. That "electron" in theory possesses both wave and particle in itself, which is beyond understanding from macro experience. So it is better to give up such a thing as "electron" and replace it with relation constructed by experience than recognize the existence of electron and suffer from spiritual torture. Good idea, isn't it? But such a good idea can satisfy us only a moment. Just think a little and we will feel an even greater torture at the idea that nature and human beings would become nothing because invisible "thing" does not exist.

The above mentioned torture may be eliminated when curvature interpretation of quantum mechanics replaces "point particle model" with "curvature model", by which undulatory property and corpuscular property of microscopic object are organically united in the same model. In different cognitive levels, "model" should be transformed, that is, "substance of appearance" will be changed, for we cannot use one model in all the cognitive levels.

Theory of interactive construction reality and curvature interpretation of quantum mechanics can be placed in the theoretical system of construction reality in present day world science and philosophy. Substance of appearance can be constructed, and because it is related to interaction and theoretical structure, it is also changeable. Noumenon is far from structure, cannot be constructed and has the attribute of continuity. Noumenon is presented through substance of appearance. Thomas Kuhn's "irreductive pat-

tern" was an error of judgment that mistook "substance of appearance" as "noumenon". In "inadequate determinism" of counter-reality theory, identical experience evidence corresponds to various different theories, and its term indicates "substance of appearance" but not "noumenon". The difference of "substance of appearance" is mainly owing to the difference of logic origin or angle of view of theoretical constructors, which is different from the transition of "substance of appearance" during the period of science revolution when experience evidences were accumulated.

8.2.2 Tian Yu Cao and Structure Reality Theory

The theory of structure reality of Tian Yu Cao focuses on the comprehension of the three concepts; noumenon, structure and construction.

8.2.2.1 Noumenon

Tian Yu Cao believes that, firstly, noumenon refers to what exists in the world; in addition, it is irreductive conceptual elements in theoretical structure of certain research sphere; as well, there is interrelation between basic noumenon and other basic existence, but the existence of noumenon does not rely on any other external things, nounmenon is real and exists independently; moreover, in determined research sphere, all appearances can be deduced from noumenon and appearance is motional result of noumenon; finally, noumenon has relative properties. The relativity of noumenon mainly lies in that: ① noumenon is final component, inseparable in analysis-reduction processes. It is objective existence determined by cognitive and experimental abilities; ② noumenon cannot be reduced to each other in different concept framework or different research spheres; ③the world has its hierarchical structure, nounmenon is not unique, each sphere has its own noumenon and there is no unique noumenon, only reduction in each sphere, so there is no universal theory.

8.2.2.2 Structure

Tian Yu Cao points out that structure is the system of stable relation of a series of components. He believes that theoretical structure is divided into mathematical structure and physical structure. Mathematical structure comes to its limit by itself, structure is prior in theory of noumenon and components are only a location-taker; Physical structure is determined by physical properties of components, and components have priority in the theory of noumenon.

In the theoretical structure of Tian Yu Cao, mathematical structure must be given physical connotation or it will be of no practical significance. The given physical connotation is physical structure which is determined by the physical properties of components, say, physical properties of noumenon; if there were no components there would be no physical structure, and then there would be no reality of physical structure. Through structure, we can see components, noumenon, and reality of structure.

Structure, the stable relational system among components, demonstrates the existence of stable interaction between components. It is stable interaction that forms the stable structure among components. Theory of interactive construction reality and structure reality are communicative.

8.2.2.3 Construction

Cao's "construction" means that, "structure of scientific theory is not unique and our cognition of the world reality is not unique. Scientific reality is constructed in specific historical period, revisable and with historical character". [12]

Tian Yu Cao emphasizes the cognition of noumenon through structure, but also believes that scientific noumenon is not unique: experience evidence is changing, theoretical structure is also changing, and these are bound to cause the change of noumenon. For example, the construction of electron experienced "cake model" of Joseph John Thomson, planet model" of Ernest Rutherford, "orbit

transition model" of Niels Bohr, "electron cloud model" in quantum mechanics, "vacuum state stimulation model" of quantum field theory, and so on.

To construct noumenon through structure, structure is real, so is noumenon. When structure changes, noumenon also changes, so noumenon is not unique and each sphere has its own noumenon.

8.2.3 The Three Editions of Theory of Structure Reality

Theory of structure reality has three different versions, the common goal of which is to oppose anti-reality theory.

8.2.3.1 J. Worrall's "cognition version"

Philosophic background of cognition version is "substance-in-itself" of Immanuel Kant, which recognizes that noumenon exists but is unknowable. What is known is form and structure, which are continuous with reality. He said, "There is continuity or accumulation in shift, but continuity lies in form or structure not in content". "What we have known is this 'form or structure' while although the content of the noumenon theory still remains, it is unknowable." [13]

The scientific background of cognition version takes electromagnetic field as an example. In scientific revolution, what is reserved in the theory of electromagnetic field is the form and structure of Maxwell equation, which is continuous and knowable, and though the content of noumenon remains, it is unknowable what on earth it is.

8.2.3.2 "Noumenon version" of Fallange and Rediman

The philosophical background of noumenon version is Immanuel Kant's "Object won't exist unless there is relation, and relation has primary qualities." [14] It is believed in the theory that there are only relation and structure in the world, object = structure = noumenon. Which is the most basic, particle or field? Wave and particle are incapable of being integrated in the same microscopic

object, quantum target is untraceable and only structure is real. They said, "… theory of structure reality with noumenon essence is re-conceptualization of noumenon: object changes to 'structure' on the basic level of metaphysics."[15]

The physical background of noumenon version may basically originate from experimental facts of wave particle duality of microscopic object. Up till now, in microscopic world, there is no reasonable means to organically unite wave particle duality to particle model and wave model. They did not try to find a new model of integration of wave and particle and seek for quantum noumenon target but attempted to re-define the conception of noumenon so as to eliminate the puzzle in cognition, which is an obvious passive solution in philosophy.

8.2.3.3 Tian Yu Cao "knowledge (or cognition) theory version"

Tian Yu Cao knowledge theory version has been briefly introduced in section two. In the cognition of noumenon, Tian Yu Cao neither agrees that noumenon is unknowable, nor relation has primary qualities and structure is noumenon. He favors to perceive noumenon through mathematical structure with physical connotation, and maintains that structure is only the system of stable relation of components. Cao believes that component comes before structure and that components itself has no structure. In our understanding, component is the noumenon expressed by structure, which belongs to the same concept of "substance-in-itself" in interaction reality theory.

Tian Yu Cao opposes relativism. He points out that, the human perception and impression should have a universally acknowledged sequence, and this is the basis of logics; in all the human knowledge structure, intrinsic stability will produce the stability of the object, and this stable object is what is regarded as noumenon (component); there is universal connection in objects, which will form cause-effect concept. [16] We believe that, in natural world,

this universal connection is four basic interactions, which will form cause-effect relations in physics and which is research target of physical philosophy.

Tian Yu Cao also believes that, his knowledge theory version focuses on encouraging physicists to explain mathematical structure in physical terms and understand structure through component, which is different from other versions. It will encourage physicists further to study the physical world so as to discover more physical substances, answer more whys and provide more interpretations of appearance, while the other two versions of structure reality theory may well be satisfied with the description of noumenon studies. [17]

Tian Yu Cao points out that, scientific objectiveness is expressed in five aspects. [18] ① constructive aspect: construct noumenon through structure; ② historical aspect: scientific development has historical period; ③ global aspect: acknowledge the existence of things beyond structural statements; ④ revisable aspect: scientific theories can be revised time and again and structure is not unique; ⑤ revolutionary aspect: when scientific theory is revised to a certain degree, new experimental evidence will cause science revolution, which may be either continuous or interruptive.

8.2.4 Interactive Construction Reality Theory—the Fourth Version of Structure Reality Theory

Interactive construction reality theory and curvature interpretation of quantum mechanics is a member of structure reality family, also named "interaction version", which is close in relation with "knowledge theory version" of Tian Yu Cao. It is illustrated from the following two levels:

8.2.4.1 Philosophical basis

① In cognition of noumenon, interactive construction reality theory regards "noumenon" as "substance-in-itself", which has either connection with or difference from Immanuel Kant's "thing-in-

itself". Their connection has the following aspects: "substance-in-itself" indicates what exists in the world. It is "thing-in-itself" formed before observation. It is real and independent existence, the basic conceptual element in conventional research spheres. The difference has the following aspects: through theoretic structure formed by interaction, we can recognize "noumenon", which is knowable. However, presentation of noumenon is determined by human abilities of cognition and experiment, and also connected with the properties of medium. To have a unified cognition of the world, what we can do is to organically and reasonably connect different cognitive levels, but not to press different cognitive levels of action mechanism into any one level (continuous effect and discontinuous effect). [19] This is basically agreeable with Cao's cognition.

② Interactive construction reality theory has introduced a concept of "substance of appearance" between "substance-in-itself" (noumenon) and "appearance". "Appearance" refers to "thing-in-itself" (sensible presentation caused by noumenon affecting on human senses), which is scattered and changeable external aspect of objects, and which has not systematically become "body". "Substance of appearance" is the systematical and stable "sensible presentation" formed by "substance-in-itself" (noumenon) in direct or indirect theoretical construction through observational signals under comprehensive action of human sense organs or the extension of the organs and cerebral nerve system. The proposition of "substance of appearance" is a supplement of scientific cognitive process, which is inaccessible in the time of Immanuel Kant. "Substance of appearance" can be constructed directly through eye-brain system in observation, indirectly through appearance, theoretical structure and logical reasoning, thus transiting "substance-in-itself" into "thing-for-us" in specific interaction (or theoretical structure). "Substance of appearance" can be constructed, through which "substance-in-itself" (noumenon) is presented. "Component

itself has no structure"[20], and "substance-in-itself (noumenon) is presented only through 'substance of appearance'". Therefore, noumenon cannot be constructed but is knowable.

In conventional noumenon theory, "substance-in-itself" (noumenon) is completely opposite to "appearance", and in philosophy, essence is regarded as opposite to appearance. With "substance of appearance", there is intercommunication between subject and object, essence and appearance, although not completely opposite to each other, they are not without difference. "Substance of appearance" is the real presentation of noumenon in human cognition.

Noumenon cannot be constructed, for it is continuous; substance of appearance can be constructed, for it can be distinguished. The "noumenon" in "inadequate determinism" and "irreductive pattern" of anti-realists is factually "substance of appearance", but not noumenon. Therefore, the two evidences counter-realists used to oppose reality theory do not exist.

③ Theoretical structure is determined by interaction. Interactive construction reality theory seems different from structure reality theory, but they are identical in essence. What kind of interaction there is, there is that same kind theoretical structure. If essential change takes place in interaction, theoretical structure will change essentially. The changes of theoretical structure of relativistic mechanics and Newtonian mechanics lie in observational action (velocity of light changes from infinite to finite); the changes of theoretical structure of classical mechanics and quantum mechanics occur in the appearance of energy quantum and the change of interaction from continuity to discontinuity. In different cognitive levels, when interaction changes, theoretical structure will change and substance of appearance will also change. Thus noumenon has its new presentation. Interactive construction reality theory, as a member of structure reality theory, reveals the dynamical cause of structural changes. Structure is not unique and communicative with

structure reality theory of Tian Yu Cao.

④ Interaction is the real final cause of objects. Each object reflects universality of connection through itself and also illustrates its own existence and reality through the universality of connection. [21] Substance and interaction of substances exist side by side; where there is substance, there is interaction of substances; with interaction there is the existence of substance. There is no such problem as to which the first is and which the second is. Interactive construction reality theory does not intensify relations, nor virtualizes noumenon, and is not in favor of relation priority, which is also the same as Cao's theory. "Substance of appearance" is the presentation of "substance-in-itself" (noumenon), "knot" of relation and inner depth of structure.

⑤ Interactive construction reality theory emphasizes human biological constructional function. It points out that, "substance of appearance" has three approaches of cognition: [22] (a) "Substance-in-itself" directly acts on human sense organs (mainly visual system) through such media as light to cause sensible presentation in human brain and constructs "substance of appearance", thus the humans know the existence of "substance-in-itself". Here, the construction from "appearance" to "substance of appearance", and then to the cognition of "substance-in-itself", is accomplished at a stretch in human eye-brain system, which is human direct biological cognition; (b) The transition of "substance-in-itself" to "substance of appearance" cannot directly be cognized by human sense and brain, but causes sensible presentation in our brain through the extension of sense organs (instrument), and then accomplishes the cognitive process in the first approach from "appearance" to "substance of appearance" and to "substance-in-itself" (noumenon). Its important difference from the first cognitive approach is: the construction of "substance of appearance" has certain external connection with human perceptual cognition, because the principle and de-

sign of instrument depends on the human obtained knowledge, theories and established logical system. (c) There is still an indirect cognitive approach of "substance of appearance". That is, when the humans cannot directly sense construction, even through instrument, natural phenomena construct "image structure" for research target through human observation and from appearance, obtained experience, knowledge, theory and logical basis. This kind of "image structure" is not consciousness; it relies on "noumenon" and expresses "appearance", so it is "substance of appearance". If it conducts as target of physical research, it is physical substance or physical reality. Substance of appearance is presentation of noumenon (in Immanuel Kant's philosophy), but not expels experiential perception (in Ernst Mach doctrine). It is the reasonable synthesis of the both. In microscopic world, in the cognition of such microscopic objects as electron, we cannot directly observe and accomplish biological construction but make the construction based on appearance, experience, knowledge, theory and relative logical reasoning. It is the human ever pursuing goal to construct "substance of appearance" of such microscopic object as electron that agrees with objective reality.

Experiential and experimental observations can only obtain appearance initially. "Substance of appearance" can be constructed through appearance by applying theoretical structure determined by interaction and combining logical reasoning, and this "substance of appearance" can return to experiential appearance through logical induction. The theory is logically compatible from beginning to end. "Substance-in-itself" (noumenon) $\rightleftharpoons$ substance of appearance $\rightleftharpoons$ appearance, it reflects the whole process of human cognition of nature. It is either suitable in experience and advantage in theory. Interactive construction reality theory has drawn on the essence of philosophical ideologies of Friedrich Engels, Ernst Mach, Immanuel Kant, and Rene Descartes.

8. 2. 4. 2 Scientific basis

① The establishment of "curvature model"

In physics, Compton wavelength λ_0 ($\lambda_0 = h/m_0c$) is often used to divide 2π ($r_0 = \lambda\!\!\!^{-}_0 = \lambda_0/2\pi$) as characteristic length of static particle. Hoffstadt, American experimental physicist, tested the distributive radius of neutron and proton in his experiment, and his test result was well suited to the experimental data, characteristic length and distributive radius of electron in the experiments of others.[23][24] This indicates that electron "image" constructed with matter wave wavelength is on experimental basis.

Static electron is not atomic electron. The characteristic length of static particle is not suitable. Atomic electron constantly moves, and its energy between energy levels is catastrophic and its effect is discontinuous. When electron transits from one energy level to another, what we can see is only frequency and intensity of light, and discontinuous spectrum. Discontinuous light spectrum cannot establish a continuous electron image. Broglie matter wave wavelength of atomic electron has space conception. Similarly, we try to use Broglie matter wave wavelength of atomic electron λ_n ($\lambda_n = h/p_n$) to divide 2π ($r_n = \lambda\!\!\!^{-}_n = \lambda_n/2\pi$), namely, radius of curvature of phase circle as reference curvature radius (r_n) of electron at energy level n in atom. In hydrogen atom, this radius r_n can just be expressed as: $r_n = na_0$, in which n is principal quantum number, a_0 is Bohr radius and $R_n = 1/r_n$ is curvature of phase circle. From amplitude of hydrogen atom and other wave function of matter wave, the curvature factor $R_n = 1/r_n$ can be separated. Expression of curvature of wave function has universal significance. Generally, the equation of wave function can be simplified as:

$$\psi = R_n G(x) \quad (\text{or } \psi = R_n G(r))$$

A reference curvature R_n on each energy level corresponds to electron; a curvature to electron at each space point changes, and electron wave is curvature wave. Bending degree of curvature ex-

presses corpuscular property, and curvature change expresses undulatory property. Undulatory property and corpuscular property are organically united in the same model in the atomic world. Therefore, electron has obtained traceable research target.

Curvature model is a kind of construction of electron "form" in specific interaction, an epitomized structure reality theory in the model of quantum mechanics. Existing quantum mechanics, the same as classical mechanics, has adopted mass-point model. However, in quantum mechanics, the attribute of interaction has been changed, theoretical structure has changed, but mass-point model which has constructed the theory has not changed. S. Sakata from Japan and Rene Thom from France both believe that this is the basic reason for the cognitive crisis arising from quantum mechanics.[25][26]

Curvature model is the reformation of mass-point model.

② Curvature interpretation may contain probability interpretation

The closer to atomic nucleus the atomic electron is, the bigger the bending degree of curvature R_n will be, and the higher the frequency of emitted photon during energy level transition; the farther away from atomic nucleus the atomic electron is, the smaller the bending degree of curvature R_n, and the lower the frequency of emitted photon during energy level transition. The closer to atomic nucleus the atomic electron is, the bigger the bending degree of curvature R_n will become, the smaller the "image" is, the higher the probability to locate "point" electron in "image", the higher the electron transition, the more intensive the light becomes; the farther away from atomic nucleus the electron is, the bending degree of curvature R_n will become, the bigger the "image", the smaller the probability to locate "point" electron in "image" is, the lower the probability of electron transition is, and the weaker the light. Curvature interpretation may completely and understandably corre-

spond to probability interpretation. Probability attribute is contained in curvature model.

It can be proved that, "image" constructed for electron with wavelength in phase space cannot be ignored in the depth of atom, and electron loses abstract condition of macroscopic mass point. [27] If atomic electron must be abstracted to "mass point", on one hand, the location of "point" electron will have error distribution, the scope of which is spreading radius of electron "image" and which shares the completely identical result with present quantum mechanics; on the other hand, mass point must be virtual and wave is real, which agrees to the mode of thinking of quantum field theory. Whether it is virtual or real, it depends on which momentum and energy are given. The transition of atomic virtual particle and substance wave to macro real particle and virtual wave has to go through quantum measurement. Quantum measurement is the process to transit discontinuous effect into continuous effect. In quantum field theory, stimulation of vacuum state and de-excitation reflects the process of continuous effect involving into quantum measurement. The involvement of continuous effect does not mean to divide quantum unceasingly, and disordered increase (increase of quantum entropy) of tested system may also gain the same results.

③ Descriptive target of Erwin Schrödinger equation

Interactive construction reality theory and curvature interpretation of quantum mechanics have made clear two kinds of descriptive targets in Erwin Schrödinger equation. Continuous spectrum may be analogical to classical fluctuation; discontinuous spectrum cannot be analogical to classical fluctuation. Energy between energy levels inside atom is catastrophic, interaction is discontinuous; virtual particle and substance wave (curvature model) is "substance of appearance" of electron, and numerous eigenstates (forming pure state) that virtual mass point (electron) simultaneously corresponds form interference wave sources independent of each other;

while quantum transition between energy levels releases photon of fixed frequency, indicating there is fixed phase difference between eigenstates at two energy levels and its corresponding appearance is wave interference; electron outside atom falls under continuous effect, "real particle and virtual wave" (mass-point model and probability distribution wave) is "substance of appearance" of electron, continuous distribution (construct mixed state) of eigenstate indicates the disappearance of interference wave sources and fixed phase difference, and its relative appearance is resonance peak (wave packet) of wave. When discussing the above two issues in phase space, eigenstate as orthogonal base in linear equation can be operated in the same mathematical way, but its physical essence is different. There should be interference of continuous effect in the transformation between the two, which is the essence of quantum measurement. In curvature model, it is very clear, but point model blurs the issue. "Curvature model" is defined with curvature of matter wave phase circle, just reflecting that "substance of appearance" is related to the nature of interaction and "substance of appearance" may return to experiential appearance through logical induction. The theory is logically compatible. [28]

8.2.4.3 Five key points of interactive construction reality theory and curvature interpretation of quantum mechanics[29]

① Put forward interaction principle. In a broad sense: indicate universal connection of objects. In a limited sense: in natural world, "image" and "state" of all objects in space-time are formed by interaction of substances, namely, the four basic interaction (gravitation, electromagnetic force, strong interaction force and weak interaction force), also including observational signal used by the humans in observing the world.

② Distinguish micro action mechanics and macro action mechanics. In micro action: energy is not continuous ($h \neq 0$), and interaction between energy levels is not continuous. In macro action:

energy level is continuously distributed, and interaction is continuous.

With different interactive mechanics and non-neglect of "image", the "model" to describe microscopic object should also change.

③ Distinguish essential difference between microscopic mass point and macroscopic mass point. In atomic depth, abstraction principle of macroscopic mass point is not suitable or cannot be copied. "Virtual particle and substance wave" (curvature model) are "substance of appearance" of micro particle. "Real particle and virtual wave" (mass-point model) is "substance of appearance" of macro particle.

④ Distinguish essential difference between quantum probability and classical probability. Quantum probability: has coherent properties; classical probability: has no coherent properties. The former is related to discontinuous effect, while the latter is related to continuous effect. The transformation of the two needs to go through quantum measurement and bring in continuous effect.

⑤ Reveal different attributes of micro space-time and macro space-time and essential difference of the two described targets in Erwin Schrödinger equation. Microscopic world: "virtual particle and substance wave" (virtual particle and real space) are basic characters, which is identical to the way of thinking in vacuum excited state of quantum field theory; Macroscopic world: "real particle and virtual wave (probability wave)" (real particle and virtual space) are the basic characters while, as to continuous spectrum, the described targets in Erwin Schrödinger equation and classical vibration have analogical character; as to discontinuous spectrum, its described target has no analogical character. The transformation of the two needs to go through quantum measurement.

To sum up, interactive construction reality theory changes the antagonism of noumenon and appearance in philosophy to the connection of noumenon (substance-in-itself or substance of appear-

ance) and appearance, thus harmonizing noumenon and appearance and eliminating the contradiction between stiff materialism and empiricism; while curvature interpretation of quantum mechanics coordinates mass-point model and fluctuation model with curvature model, so the antagonism of particle-fluctuation is changed to the unity of particle-curvature-fluctuation, contradiction caused by separation of wave and particle is eliminated and historical puzzle that quantum target is untraceable is solved. Substance of appearance and curvature model is the link in coordinating and unifying the existing contradiction in scientific philosophy and quantum mechanics. There are no diametrical things in the world, so the key is to have ways to coordinate them and establish proper models. Nature is harmonious, so is society.

8.3 Superiority of Curvature Interpretation of Quantum Mechanics

If the theories of "quantum mechanics interpretation" of these tens of years are classified, they may fall into three classes: ① probability interpretation of Copenhagen School; ② substance wave interpretation with Erwin Schrödinger and Louis de Broglie as the representatives; ③ ensemble interpretation with K. Popper and Blokhintzev as its representatives. Probability interpretation of Copenhagen School believed that, wave function $|\psi|^2$ represented probability density of the appearance of micro particle, and uncertainty principle indicated location and momentum of microscopic object possessed natural uncertainty; Erwin Schrödinger believed that $|\psi|^2$ represented density distribution of mass and electrical charge of micro particle, possessing fluctuation with substance properties as electromagnetic field, while uncertainty is distribution width of wave packet; Broglie's understanding of wave function is that particle rides on the wave, wave leads particle; in the theory

of double waves (double solutions), non-linear solution (particle) is in the middle while linear plane wave is around, which is called "discus model"; because it is difficult in mathematics, its development is very slow. However, Sir Karl Popper and Blokhintzev regarded $|\psi|^2$ as probability distribution of large amount of micro particles, not different from probability distribution of macro particle; uncertainty principle is the spreading statistical relation of location and momentum of micro particle. Copenhagen probability interpretation acknowledges undulatory property of single particle, which has been proved by experiment, but microscopic object is given natural uncertainty, which is rather unacceptable. Erwin Schrödinger describes corpuscular property with wave packet, but wave packet scattering is denied through experiments; Blokhintzev ensemble interpretation has affirmed probability distribution of large amount of particles, but denies undulatory property of single particle as premise, while undulatory property of single particle is confirmed through experiments.

These are all problems.

In order to eliminate contradiction in the above interpretations, the scientists have made many revisions for tens of years. The more successful work should include Von Neumann axiomatized interpretation system of quantum mechanics, David Bohm quantum potential interpretation, multi-world interpretation and quantum decoherence interpretation. Strictly speaking, multi-world interpretation and quantum decoherence interpretation should be the further revision of Von Neumann theory of wave packet collapse, while Von Neumann interpretation should be the systematization of Copenhagen School interpretation. Von Neumann theory of wave packet collapse violated the locality principle of theory of relativity, and David Bohm quantum potential was not clear in physical sense, as some people criticized, between wave function and quantum potential, there seemed to be circular argument, and on the level of

special theory of relativity level, introduction of "ether" was suspected. Multi-world interpretation was self-believed to have cast off wave packet collapse, but gave uncertainty to man's subject position in multi-world. Quantum decoherence interpretation considered it might eliminate non-locality of wave packet collapse, but brought about logically incompatible model itself (analyzed by Zhao Guoqiu). In short, although existing interpretation of quantum mechanics has made great achievement, there are still many left to be discussed, "argument is still going on". This is environmental basis of the appearance of *Interactive Reality and Curvature Interpretation of Quantum Mechanics*.

In my opinion, an independent interpretation of quantum mechanics must have its independent interpretation to wave function $|\psi|^2$, uncertainty principle $\Delta p \cdot \Delta x = \hbar$ and quantum measurement, the three of which must be uniform in logics. Copenhagen probability interpretation, Erwin Schrödinger wave packet interpretation and ensemble interpretation of Sir Karl Popper and Blokhintzev, all have their own independent comprehension to wave function $|\psi|^2$ and uncertainty principle. In David Bohm interpretation, although there is a new quantum potential (in fact, Louis de Broglie has put forward), but the new comprehension of wave function is suspected to have circular demonstration. The comprehension of curvature interpretation of quantum mechanics to wave function $|\psi|^2$, uncertainty principle and quantum measurement has its own different cognition; therefore, curvature interpretation of quantum mechanics is a new interpretation independent of other interpretations.

Now we can compare curvature interpretation of quantum mechanics with other interpretations so as to see whether curvature interpretation of quantum mechanics is relatively superior in solving some difficult problems.

① Curvature interpretation of quantum mechanics believes

that mathematical form of existing quantum mechanics is perfect, no need to made any new revision and complement, which guarantees the correctness of taking quantum mechanics as theory of unique appearance in tools and applying level.

② According to Wan xiaolong's analysis, existing interpretation system of quantum mechanics lacks analysis of microscopic object "image" from wave function to sensate object, and directly jumps from "number elements" to "sensate object", thus causing confusion of cognition. Curvature interpretation of quantum mechanics compensates for this cognitive process just in time. In atom, "image" of microscopic object cannot be observed directly, but may be constructed through matter wave wavelength $\frac{\lambda_n}{2\pi} = r_n$. r_n is spherical radius of "substance of appearance" of micro particle. In hydrogen atom, r_n and Bohr radius a_0 possess the same meaning, namely, $r_n = na_0$, n is principal quantum number. In discussing atom issues, the influence of microscopic object "image" on the discussed issues can be ignored. In Newtonian mechanics, abstractive principle of macroscopic mass point is not suitable in atomic world (or can not be copied), which is the basic cause of the production of the puzzles in quantum mechanics interpretation.

③ Wave function $|\psi|^2$ describes the law of change of microscopic object "image" in atomic world, characterized by objective "surface curvature". Electron wave is curvature wave, bending degree of curvature indicates corpuscular property, and curvature change indicates undulatory property. Cognition of wave-particle duality of microscopic object has reached its perfect unity. Wave-particle contradiction in Copenhagen interpretation of quantum mechanics is also well solved in the new model. Wave function is objective and real. Niels Bohr philosophical principle of wave-particle complementary is not necessary.

④ Curvature interpretation and probability interpretation can

be interchanged. When "image" is big, "surface" curvature is small, and the probability to locate point particle in "image" is small; when "image" is small, "surface" curvature is big, the probability to locate point particle in "image" is greater. Curvature $R(R = \frac{1}{r})$ and the probability to locate point particle in "image" is in direct proportion. In atom, if principal quantum number $n \to \infty$, $R \to 0$ and $\rho \to 0$. Wave function in curvature interpretation has double attributes, whose whole calculating results are agreeable with probability interpretation of quantum mechanics. Curvature interpretation contains the reasonable part of probability interpretation.

⑤ "Uncertainty" is not the natural character of object, but the error caused by measurement when abstract principle of macroscopic mass point in Newtonian mechanics does not suit (cannot be copied) in atomic world and microscopic object "image" cannot be ignored. Uncertainty principle, with the background of reality theory, cannot be used as evidence of non-determinism. Quantum mechanics is still determinist (or intrinsic imperfect determinism). There is no contradiction between non-determinism and determinism of relativity theory in quantum mechanics.

⑥ There is essential difference in action mechanics of macro world and microscopic world. Discontinuous effect of microscopic world causes catastrophe between energy levels——the cause for the production of independent interference wave sources. Quantum measurement is the process that continuous effect interferes and eliminates independent interference wave sources. Quantum entanglement of decoherence is the preand post entanglements of microscopic object state in measurement. Microscopic object state disappears in catastrophe in self-entanglement, and the system transforms from pure quantum state to mixed state. Schrödinger's cat paradox is solved automatically. Pure quantum state with coher-

ence corresponds to discontinuous numbering of physical state and mixed state with coherence disappeared corresponds to continuous numbering of physical state. The former corresponds to discontinuous effect while the latter to continuous effect.

"Wave packet collapse" does not exist in quantum measurement. In measurement, catastrophic eigenstate changes from catastrophe to continuity owing to the interference of continuous effect of instrument, and eigenstates all simultaneously return to macro world (change to continuous spectrum). However, instrument recognizes them in random, thus eliminating the non-locality contradiction in measurement. In Albert Einstein EPR experiment, non-locality is correlation between spaces, which is originated from curvature properties of wave function, without energy transmission, and not contradicting the theory of relativity.

⑦ The human cognition of the nature cannot be separated from interaction, the principle of which is philosophic foundation of curvature interpretation of quantum mechanics. Therefore, we put forward interaction reality. In the natural world, the human cognition of object "image" has relation with interactive properties. In macro experiential world, the continuity of action makes human eye-brain system directly perceive objective "shape" which can be regarded as unchangeable in experience. It is not the case in microscopic world: in atom, the "image" we construct for microscopic object through experimental appearance is changeable. Nevertheless, different energy level has a basic state of "image" ($r_n = na_0$), the curvature it corresponds is called reference curvature, expressed in wave function amplitude. It is real function, vector absolute value, not contradicting to the definitions of property of complex number of wave function and curvature. Reversely, it is curvature property of wave function and vector that determine complex number property of wave function. Curvature may be vector of complex number coordinate system plane surface. Probability

vector is not easy to understand while curvature vector is.

⑧ In quantum mechanics, physical reality should be understood on three different levels: (a) to pure quantum state, substance wave and virtual particle are physical reality that the theory describes, "ghost particle" and substance wave may well explain two-slit experiment; (b) to mixed state, real particle and virtual wave (empty wave, "ghost field") are physical reality the theory describes; (c) to classical electron theory, substance electron——mass point is physical reality the theory describes. In natural world, on different cognitive levels, the expression of physical reality the theory describes is different. We cannot run through all the cognitive levels with an identical physical reality.

⑨ Quantum potential in David Bohm's theory is equal in value to "curvature potential——space structure" in curvature interpretation and physical significance of curvature potential is even more explicit. It expresses a structure in Hilbert space. Curvature interpretation may also give its corresponding interpretation to Erwin Schrödinger substance wave, guided wave of Louis de Broglie wave, and multi-world of the multi-world interpretation. Curvature interpretation has more comprehensive containment in understanding statistic ensemble interpretation, logic developing basis of stochastic process interpretation, and analysis of what on earth they have lost.

It is demonstrated after research that, for multi-particle system, curvature interpretation of quantum mechanics also has its relevant theoretical pattern.

⑩ Theoretical prediction: (a) If the human beings can produce "macro pure quantum state" with atomic internal catastrophic mechanism, quantum computer may come into being. Otherwise, owing to the information loss caused by decoherence, attempt to make quantum computer needs discussion. (b) Owing to the variety of interaction, in the transition from "substance-in-itself" to

"substance of appearance", it is difficult to explore "primary substance" and "physical reality" that construct the world, but we may theoretically discover logic interface between different cognitive levels and construct the unity of cognition of the world. (c) In Coulomb Blockade Effects, if tunneling aperture where electron is located is not too bigger in size than electron wavelength, Coulonb Blockade will be ineffective.

Reference

[1] Shoichi Sakata. Shoichi Sakata Collected Works of Science & Philosophy [M]. Translated by An Du. Beijing: Knowledge Publishing House, 1987:140

[2] Rene Thom. Mathematical Models of Morphogenesis [M]. Translated by Zhou Zhongliang. Shanghai: Shanghai Translation Publishing House, 1989:215-280。

[3] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics. China News United Publishing House, Jan. 2007: 47-73, 75-101, 129-156.

[4] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics. China News United Publishing House, 2007: 159-170, 221-235.

[5] R. P. Feynman, C. Miller et al. Contemporary Physics [M]. Translated by Ye Rui et al. Beijing: Science Publishing House, 1981:168-173.

[6] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics [M], China News United Publisher. 2007:12.

[7][8] Zhao Guoqiu. Re-Consideration of Quantum Decoherence Interpretation [J]//China Basic Science, 2006(8).

[9][11][12][14][16][17][18][20] Wang Wei. Analysis of Constructive Reality, Studies in Dialectics of Nature [J]. 2006(11):34-38.

[10] T. Kuhn. The Structure of Scientific Revolutions [M]. University of Chicago Press, 2nd Enlarged Ed, 1970:206.

[13] J. Worrall. Structural Realism: The Best of Both World? [J]. Dialectica, 43, 1989:99-124.

[15] S. French, J. Ladyman. Remodeling Structural Realism: Quantum Physics and the Metaphysics of Structure [J], Syntheses, 136, 2003:37.

[19][21] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics[M]. China News United Publisher, Jan. 2007:47-74, 75-102.

[22] Zhao Guoqiu. Substance-in-itself, Substance of Appearance and Physical Reality // Studies in Dialectics of Nature [J]. 2006(11):39-41.

[23] R. P. Feynman, C. Miller et al. Contemporary Physics [M]. Translated by Ye Yue et al. Beijing: Science Press, 1981:163-168.

[24] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics [M]. China News United Publisher, 2007:141-143.

[25] Shoichi Sakata. Shoichi Sakata Collected Works of Science & Philosophy [M]. Translated by An Du. Beijing: Knowledge Publishing House, 1987:140.

[26] Rene Thom. Mathematical Models of Morphogenesis [M]. Translated by Zhou Zhongliang. Shanghai: Shanghai Translation Publishing House, 1989:208-215.

[27] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics [M]. China News United Publishing house, 2007:83-85.

[28] Zhao Guoqiu, Gui Qiquan. Curvature Interpretations of Quantum Mechanics & the Unity of Wave-particle Duality// Collected Papers of The 13th International Conference for Logics, Methodology and Science & Philosophy, 2007:426.

[29] Zhao Guoqiu. Between Physics and Philosophy—Interactive Reality & Curvature Interpretation in Quantum Mechanics [M]. United Press of China Information, China News United Publisher, Jan. 2007:10-23,75-103,129-159.

Note: [10][13][15]Quotation from Wang Wei. Analysis of Constructive Reality//Studies in Dialectics of Nature [J]. 2006 (11).

第 八 章
结构实在论的第四版本

现在我们有条件对量子力学曲率解释的理论基础作出相应的归纳。

第一节　实验现象、物理模型与量子测量

点粒子模型是现今量子力学解释体系诸多逻辑矛盾产生的总根源。[1][2]修改量子力学中的点粒子模型是消除这些逻辑矛盾的必要途径。曲率模型通过物质波波长，由相位圆定义、建构的微观客体的“形态”($r=\lambda/2\pi$)，在讨论原子问题时，其大小不可忽略。经典力学中质点抽象原则不适用于原子世界或不能照搬。

把原子中的量子现象转变为宏观经验中的经典力学研究对象，必须将能量的非连续分布转变为连续分布，将非连续作用转变为连续作用。这就是量子测量的基本任务。

一、量子力学波粒二象性物理模型的建立

质点是牛顿力学、相对论力学描述的物理实在。客体所具有的能量、动量、位置和时间都赋予了没有几何大小的质点。给予一定的边界条件，建立质点的运动方程，就可以知道运动物体的过去、现在和未来。决定论是牛顿力学和相对论力学的共同特征。在宏观低速和宏观高速运动中，牛顿力学和相对论力学用质点模型讨论物理问题，与实验现象符合得很好。

现今的量子力学人们仍然使用质点模型。但在认识量子力学数学形式的物理意义并与实验现象相比对时，问题变得十分复杂。较

为流行的量子力学解释就有七八种，每一种解释都通过一个物理模型，试图建立量子力学数学形式与所描述的物理实在之间的内在联系，它们既有成功，也有令人不快的遗憾。

纵观历史，在讨论具体的原子问题并解释实验现象时，在点粒子的基础上，卢瑟福提出了原子的太阳系行星模型；玻尔提出了原子中电子轨道能级跃迁模型；爱因斯坦提出了光量子模型；海森伯提出了可观测量矩阵模型；薛定谔提出了波包模型；德布罗意提出了导波和双重解模型；玻姆提出了量子势模型；量子场论则建立了真空激发态模型。

上述各种模型的建立，关键在于寻求合理解释微观世界融波粒于一身的物理机制和产生途径。卢瑟福模型建立在经典力学点粒子模型之上，既不能解释原子的稳定性，也与波动现象无缘，只好被放弃；玻尔的能级跃迁模型较之卢瑟福模型有了很大的进步，虽然解决了原子的稳定性问题，但四个量子数仍然只是一个外在的假设，微观客体的粒子性和波动性也只能用互补原理来加以解释，很难令人满意；1905～1916 年间，爱因斯坦建立的光的能量与频率，动量与波长之间的关系：$E=h\nu$、$p=h/\lambda$，只是给出了粒子与波形式上的对应，谈不上揭示二者本质上的内在联系；海森伯的矩阵模型虽然很好地概括了原子现象之间的关系，但却赋予了微观客体天生的不确定性，尽管他为玻恩的概率波提供了力学根据，却遭到了爱因斯坦的强烈反对；薛定谔建立了微观粒子的波动方程，提出了实物粒子的波包模型，但波包扩散被实验否定，波包模型没有被广泛接受；德布罗意的导波和双重解模型，因数学困难发展十分缓慢，短期内难以看到优势；冯·诺依曼是哥本哈根学派理论的推进者，其公理化解释体系的建立，将人们对波粒二象性的理解提高了一大步，但冯·诺依曼波包坍缩困难却令人不可思议；退相干解释试图解决这一困难，但理论的逻辑结构仍有值得推敲的地方；玻姆的量子势模型是典型的将微观粒子等同于宏观粒子思维模式的产物，量子势物理意义不明确，或波函数与量子势之间有循环论证之嫌，一直受到物理学家的责难；量子场论是目前大家看好的模型，但点粒子实体地位的存在，对解决双缝实验难题仍然难有作为。

上述诸模型中，卢瑟福、玻尔、海森伯、玻姆模型等，可以说粒子

是基本的；而薛定谔、德布罗意模型等表面上看波是基本的，但思想深处仍有点粒子背景；量子场论中波是基本的，粒子由真空场激发出来，波和粒子的共存有了新的理解。然而，不管哪种模型，波和粒子均是两个分立的概念，被撮合在同一模型中。

建立一个波粒实质统一的模型，是量子力学发展的必要，也是认识微观客体波粒统一物理本质的必须。在桂起权倡导的科学共同体中，赵国求在分析微观粒子具体波函数数学结构及其内部空间相位圆的特征时，提出了微观粒子的曲率模型，并把由此建立的量子力学解释体系，称作量子力学曲率解释。

二、量子力学曲率解释

量子力学曲率解释的基本要点是：[3]

①承认电子等微观客体不是质点，波函数是对自身时空特征的描述；

②由德布罗意物质波波长（$\lambda_n/2\pi=r_n$ 相位圆的曲率半径），在内部空间定义、建构微观客体电子等的"形态结构"；

③本征态由"形态结构"给出的基准曲率 R_n 和函数 $G_n(x)$ 组成

$$R_n=1/r_n,\quad r_n=\lambda_n/2\pi$$

氢原子中，λ_n 为能级 n 的德布罗意驻波波长。本征态波函数可以写成：

$$\psi_n=R_nG_n(x) \tag{8.1}$$

本征态的叠加形式是

$$\psi=\sum_{n=1}^{n}R_nG_n(x) \tag{8.2}$$

式(8.1)、(8.2)均可在量子力学现有波函数振幅中通过提取公因子 R_n 得到。量子力学现有数学形式不变，但物理内涵明确。

④曲率和概率可以相互转换。曲率大，概率大；曲率小，概率小；曲率为零，概率为零。

R_n 与实验现象的对应是：曲率大，"形小"，在"形内"找到点电子的概率高，电子的跃迁频率高，光的亮度强；曲率小，"形大"，在"形内"找到点电子的概率低，电子的跃迁频率低，光的亮度也弱；"形无穷大"（离原子核无穷远处），曲率为 0，在"形"内找到点电子的概率

为 0，光的亮度为 0。

曲率解释可以包容概率解释，并与实验现象有很好的对应。

⑤物质波是曲率波（但有概率属性），曲率的大小表示粒子性，曲率的变化表示波动性。曲率波将微观客体的粒子性和波动性有机地统一在同一模型中，克服了前述所有模型中波粒概念分立缺陷和点模型对微观客体“形”的丢失，使数学波变成了物理波。

在由客体“形态”构成的“内部空间”中，能量、动量赋予了“空间”，波是实的，粒子是虚的，虚质点没有运动轨迹；在“外部空间”，能量、动量赋予了点粒子，粒子是实的，波是虚的（概率波），实粒子有运动轨迹。量子测量则是一个通过连续作用的介入，消去能量的非连续变化，将内部空间的实体波、虚粒子（虚质点）转化为实粒子、虚波（概率波）的过程。

三、曲率波实例研究[4]

（一）氢原子

对于氢原子，曲率波波函数由原波函数变形而来，具体形式是：

$$\begin{aligned} R(r) &= (1/na_0)2B_0 e^{-\frac{\rho}{2}}\rho^l \angle_{n+l}^{2l+1}(\rho) \\ &= R_n 2B_0 e^{-R_n r}(2R_n r)^l \angle_{n+l}^{2l+1}(2R_n r) \\ &= R_n G(r) \end{aligned} \tag{8.3}$$

(8.3)式中 $R_n=1/na_0$，而 $na_0 = r_n = \lambda_n/2\pi = \bar{\lambda}_n$，$\lambda_n$ 是氢原子中电子的德布罗意驻波波长。R_n 就是我们定义的第 n 个能级上电子的基准曲率。通过它可定义、建构电子的基本“形象”。

氢原子中的电子波就是以基准曲率 R_n 为振幅的曲率波。曲率与电子的跃迁概率成正比，概率和曲率可以相互转换，曲率中包含有概率属性。

其他任何物质波波函数其振幅中均可分离出一个由物质波波长 λ_n 定义的基准曲率半径 r_n 或曲率 R_n，曲率解释具有普遍性。

（二）康普顿物质波

人们常用康普顿波长 $\bar{\lambda}_0$、λ_c 代表粒子的线度是有道理的。

A. 静态康普顿物质波 ψ_0

$$\psi_0 = a_0 \exp\left[\frac{i}{\hbar}(p_0 \cdot r - E_0 t)\right] \tag{8.4}$$

(8.4)式中 $p_0=m_0c, E_0=m_0c^2$，m_0 是粒子的静质量，$a_0=\dfrac{1}{r_0}=\dfrac{1}{\lambda_0}=\dfrac{1}{\hbar/m_0c}=\dfrac{m_0c}{\hbar}=R_0$。所以，康普顿静态物质波是曲率波。由于 $p_0\cdot r=0$，实际上这个波是无法观察的。（具体讨论见附录 2）

B. 动态康普顿物质波 ψ_c

$$\psi_c=a_c\exp\left[\frac{i}{\hbar}(p_c\cdot r-E_ct)\right] \tag{8.5}$$

(8.5)式中 $p_c=mc, E_c=mc^2$，m 是粒子的动质量。

$$a_c=\frac{1}{r_c}=\frac{1}{\lambda_c}=\frac{1}{\hbar/mc}=R_c$$

所以，康普顿动态物质波也是曲率波。由于 $p_c\cdot r\neq 0$，它在三维空间有分量，这个波是可观察的。

R_0、R_c 代表了粒子在不同状态下的结构，霍夫斯塔特通过实验测得的中子、质子及尔后其他人用实验测得的电子电荷的分布半径，均与用 R_0、R_c 计算所得结果符合得很好。[5]

四、薛定谔方程的描述对象

（一）经典力学波的叠加

若 y_1、$y_2\cdots y_n$ 是线性波动方程的解，则 $y=y_1+y_2+\cdots+y_n=\sum\limits_{n=1}^{n}y_n$，亦是方程的解。子波 y_1、$y_2\cdots y_n$ 通过媒质中同一点所引起的质点总的运动效应，等于各子波单独作用同一质点所引起的运动效应的总和。由于经典波动方程是时空的偏微分方程，因此，各子波对质点的作用被看作是连续的，质点在运动中能量变化也是连续的。

为了更好地理解量子波动，对经典波动现象可作如下简要分析：

①若 y_1、$y_2\cdots y_n$ 等子波之间无固定周相差，则在汇集于某点的子波的作用下，该点将显示出“拍”的共振现象。如图 8.1。

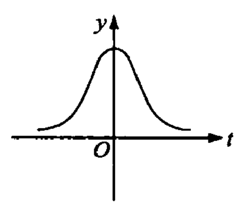


图 8.1　波的叠加形成的共振峰图像（波包）

②若子波 y_1、$y_2\cdots y_n$ 之间有固定周相差，对于媒质中不同时空点，波的

传播和叠加可能造成有些点振动始终加强，有些点振动始终减弱，这就是波的干涉现象。双缝干涉就是典型一例。

波的干涉的必要条件是：独立的相干波源和波源之间固定的周相差。

③可以对任意一质点的共振曲线进行傅立叶展开，则分解出来的子波来源于同一质点的不同振动形式。质点的振动，变成了各子波的共同波源。可见，经典力学中不同子波，可以交汇于一点，形成质点的共振图像；反过来，这个质点的振动也可以看作一个波源，并且可分解成许多彼此独立、能量连续、作用连续的子波，并且子波之间没有相干性。

经典力学中，由质点的概率分布形成的波动图像中，质点是实体的（能量、动量赋予质点），波是虚的，波只是质点在时空序列中的一种分布函数（相位波）。

（二）量子力学中波函数的叠加

量子力学中薛定谔波动方程是通过经典类比得到的。若 ψ_1、$\psi_2 \cdots \psi_n$ 是线性波动方程的解，则 $\psi=\psi_1+\psi_2+\cdots+\psi_n=\sum_{n=1}^{n}\psi_n$ 也是方程的解。根据经典类比条件，子波（本征态）ψ_1、$\psi_2 \cdots \psi_n$ 之间能量和作用亦应是连续变化的，因此，薛定谔认为，他的方程不需什么量子跃迁之类的概念。电子波像无线电波一样，具有实体性，是质量或电荷的密度分布。电子的粒子性由波包来量度。波包扩散被实验否定，波包模型未能被广泛接受。此外，将薛定谔方程应用于具体物理对象（如氢原子等）时，必须假定方程中的待定系数（能量）只能作非连续变化，才有符合物理实际的解，这表明，原子中的电子跃迁概念不能忽视。原子中与同一电子对应的诸子波（本征态）之间能量是突变的，作用不连续，有作用量子存在！两个能级之间：$E_2-E_1=\mathrm{h}\nu$，由于 $\mathrm{h}\nu$ 的不变性，它预示对应两个本征态之间有固定周相差，本征态之间有相干性。

以二能级为例：

$$|\psi|^2=|\psi_1+\psi_2|^2=|\psi_1|^2+|\psi_2|^2+\psi_1^*\psi_2+\psi_2^*\psi_1$$

$\psi_1^*\psi_2+\psi_2^*\psi_1$ 为干涉项，ψ 是量子力学中的纯态波函数。

原子内部，由于独立相干波源的存在，与电子对应的诸子波（本

征态)不能形成电子单一的共振峰，只能形成相应的干涉图像。如图8.2。

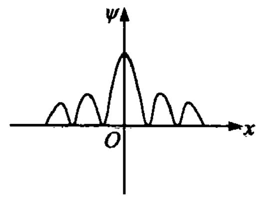


图 8.2 电子波二能级干涉图像

电子能量的不连续，能级间作用不连续，既使原子中的电子“整体形象”具有离散性，也使电子能同时对应诸多彼此独立的、平行的具有相干性的子波波源。一个粒子具有离散的“整体形象”，并能以波的相干形式出现，能量、动量赋予了波，显然，波是实体性的；离散的“整体形象”是什么？当然不可用宏观点粒子言喻。与宏观经验相比，粒子的“集中形态”显然只能是虚的。前述曲率模型正好体现了原子中微观客体这一本质特征。这是薛定谔方程描述的一个层次。

在原子外部(零势面以上)，电子的能量可以连续分布，解的叠加形式变为

$$\psi = \int \varphi(x)\mathrm{d}x$$

$\varphi(x)$是连续谱本征态，本征态之间固定周相差消失，本征态之间没有相干性。粒子可以恢复实体的“集中形态”。ψ正是连续谱构成的波包。当“形”被忽略时，薛定谔的波包代表的是具有局域“整体形象”的经典粒子——质点的运动形态。由于相干性的消失，ψ是一个混合态。这是薛定谔方程描述的又一个层次。在这一层次中，当粒子的“形”被忽略以后，粒子是实体性的，波是虚的。波是实体粒子的概率分布函数。它正是薛定谔方程可作经典类比的依据。

微观客体，无论是具有离散“整体形象”特征的纯量子态，还是具有局域“整体形象”特征的混合态，它们在薛定谔方程中各自的演化均是可逆的。但纯态到混合态的演化不可逆，因为它涉及到从原子内到原子外，能量非连续分布(求和：数学上用 $\sum$ 表示)到能量的连续分布(求和：数学上用$\int$ 表示)，相互作用从不连续到连续，电子从实体波、虚质点到实质点、虚波，事物从量变到质变的飞跃。量子测量中连续作用的介入，消除能量的非连续分布，正好能实现这一量变到质变的飞跃。[6]

五、量子测量的本质

现在我们可以对量子测量的本质做出新的解释：

所谓量子测量，本质上就是通过测量仪器（或别的外界环境），对被测系统（S）施加一个类似于连续的相互作用，让被测系统（S）的能量状态由不连续变化变成连续变化。这样，既可消除突变的独立相干波源，也可消除子波之间的固定周相差，使被测系统相干性条件完全丧失。实验现象上，将出现多峰的相干波转变为单峰的共振波包。

仪器（M）（或环境）对系统（S）提供一个连续的相互作用，将纯态变成混合态，并不意味着要无限分割量子，当把整齐的量子跃迁变得杂乱无章时，动量的绝对值不变，方向却发生了改变。从整体上看，能量和相互作用的非连续性就类似地消失了。这无异于是量子熵的增加，人们将量子熵的增加与量子测量联系在一起，是有道理的。根据新的量子测量机制，被测系统连续作用向非连续作用转化的逆过程也可能存在。但这种逆过程不适用于可自动退相干的宏观测量仪器。

玻尔认为量子测量是仪器对微观被测系统施加了一个不可控制的相互作用，在相应的本征态上产生一个任意的相角，使被测系统的相干性消失。实际上，现在我们看到，不是"不可控制的相互作用"，而是仪器提供了一种连续作用。所谓的任意相角，则来源于能量由突变到连续变化，消去了固定的周相差。被测系统产生相干的两个必要条件在系统与仪器的相互作用中均被失去，相干性消失是自然的。

如果说玻尔的测量理论是宏观测量仪器对微观被测系统的作用，使微观被测系统由纯态变为混合态，那么，冯·诺依曼的思维方式则是反玻尔而行之。他将宏观仪器首先假设为纯量子态，纯态的仪器与纯态的系统发生相互作用将不改变系统的状态，只改变测量仪器的状态。仪器退相干了，从仪器的状态就可"读出"被测系统的状态。我们对以冯氏理论为基础的量子退相干理论进行过分析（第六章第三节），如果仪器能在瞬间自动退相干，那么纠缠态

$$\psi=\sum_{n}C_n|n\rangle|e\rangle \tag{8.6}$$

就只有数学意义而无物理意义。由于仪器自动退相干，实际物理测

量中，(8.6)式中不可能有纯态仪器存在，这将引起量子力学退相干理论体系内的逻辑不自洽。[7]因此，退相干理论的后继推广将都是多余的。

如果考虑量子测量是仪器对被测系统提供了一个连续作用，使被测系统由纯态变成混合态，那么量子纠缠将可理解为测量中被测系统自身前后态的纠缠。[8]也正是这种自纠缠实现了能量由突变到连续的转化，从而系统的相干性消失。显然，冯·诺依曼对仪器所做的纯量子态假设也将是多余的。

第二节　相互作用建构实在论——结构实在论的第四版本

相互作用建构实在论是结构实在论中的一员。相互作用是结构的动力学成因，曲率模型是量子力学理论结构的具体化。“现象实体”、“曲率模型”是科学哲学与量子力学中现有矛盾协调统一的纽带。

一、科学哲学中的实在论与反实在论

科学理论中名词术语所指称的“东西”，诸如电子等微观客体是否真实存在，实在论者与反实在论者有完全相反的回答。实在论者认为科学理论中名词术语所指称的“东西”，比如电子，尽管看不见，但它真实存在，真有其“物”。而反实在论者则否认或怀疑科学理论中电子等微观客体的客观实在性，否认或怀疑电子等真有其“物”。

科学实在论者认为科学理论中电子等微观客体真有其物的基本依据是[9]：

①理论术语与观察术语不可截然区分，理论术语指称的“东西”，今天虽不可观察，但科学的发展会提供可观察性。比如细胞，最初看不到，但后来用显微镜就看到了。世界上原则上没有不可观察的东西，今天是理论术语，明天可能就是观察术语。理论术语指称的是客观实在。

②最佳说明推论。哈曼(G. Harmam)认为，一个理论比它的竞争者能更好地说明经验证据，这个理论应更优越，我们更有理由相信它。

③微观结构确实存在。科学理论常用指称的微观结构说明现象。塞拉斯(W. Sellas)认为,科学需要相信这些不可观察的微观结构。例如构成核子的夸克,超导理论中引入的"库柏电子对"。科学家很难不相信这些看不见的"夸克"、"电子对"的存在,而只相信由它们产生的可观察现象。

④无奇迹论证。如果不相信理论为真,那么,我们只能承认现代科学的成功是一个"奇迹"。"奇迹"是指可以没有道理出现的事物,科学不应是没有道理的。实在论是使科学不成为"奇迹"的唯一哲学。

反科学实在论者否认科学理论中电子等微观客体真有其物的依据是:

①给定的经验证据,可以对应很多逻辑自洽的理论。如果理论术语所指是"真",到底哪种理论所指为"真"呢?要知道,每一种理论都是依据相同的经验证据啊!反实在论者得出结论:经验证据不能决定科学理论的真假。这叫"不充分决定论旨"。

②科学革命之后,新、旧理论范式之间具有不可通约性。原科学理论中的本体论概念,在新的科学理论中得不到承认。燃素、以太即为事例。库恩称:"我没有看到(在理论更替中)本体论发展的融贯方向。"这叫"本体论不连续性"。[10]

科学没有发生革命,"本体"就"不充分决定",科学革命后,"本体"完全不连续,这样的"本体"还存在吗?以前的理论术语现在不再有所指了,现在有所指的理论术语,将来也不会有所指。理论术语所指不是实在。

现代反实在论的代表人物范弗拉森对实在论提出了批评。[11]他说:麦克斯韦只是论证了观察与不可观察的区分是含混的,并未明确指出不可区分对微观客体的观察是间接的;最佳说明推论只是心理假说,更能说明经验证据的理论,只是经验适当的;并不是所有的科学现象都需要进一步说明,概率波背后不需要"隐参量"支撑;现代科学之所以成功,是我们淘汰了失败的理论。这表明,科学不是发现了真理,而只是经验适当的。

我们认为范弗拉森新理论"淘汰"旧理论的说法不太准确。合理的说法应是新理论"取代"旧理论。"取代"包含有两层意思:一是用

正确的“取代”错误的，一是用完善的“取代”不完善的。相对论力学对牛顿力学的发展，并不意味着牛顿力学被淘汰，而是意味着相对论力学比牛顿力学能说明更多的自然现象，回答更多的为什么，给出更多的预见。新理论比旧理论表现得“更佳”。科学革命常常体现为人类认识层次的深入和深化。

依据相互作用建构实在论，人类的直接经验，多是直接生理建构的产物。人对自然的认知，最初只能是现象。现象背后的“东西”是什么，要靠理论结构和逻辑推理去建构。这样建构出的“东西”，还只是“现象实体”或“物理实体”。它是“本体”在具体相互作用，包括观察作用(理论结构)中的呈现。“现象实体”(物理实体)是实在的，它可以通过逻辑反演还原为现象，因此，它是经验上可以接受的。

反实在论者否认理论术语所指真有其物，恐怕主要还是来源于对电子的认识。那个理论上的“电子”集波粒于一身，这是宏观经验完全不能理解的。与其承认真有“电子”而饱受精神折磨，不如放弃“电子”真有其物，由经验建立的关系取代。这样岂不来得更轻松，更痛快？但这种痛快只能满足于一时，仔细一想，看不见的“东西”都无有其物，那自然和人类都终归子虚乌有了。这是更可怕的折磨。

量子力学曲率解释用“曲率模型”取代“点粒子模型”，可以消解上述折磨。微观客体的波动性和粒子性，有机地统一在同一模型中。不同的认识层次，“模型”要发生转换，也就是“现象实体”要发生变化，我们不能用一种模型贯穿所有的认识层次。

相互作用建构实在论和量子力学曲率解释，可以纳入当今世界科学哲学中结构实在论体系。现象实体可以建构，与相互作用及理论结构有关，是可变的；本体谈不上结构，不能建构，有连续性；本体通过现象实体给予呈现。库恩的范式不可通约，是误把“现象实体”当“本体”所做出的判断。反实在论“不充分决定论旨”中，相同的经验证据对应有多种不同的理论，其术语所指亦是“现象实体”，不是“本体”。“现象实体”的不同，主要是理论建立者的逻辑起点或视角有差异，与科学革命时，经验证据增多，现象实体的转换是有区别的。

二、曹天予的结构实在论

曹天予的结构实在论体现在对本体、结构和建构等三个概念的

理解上。

(一)本体

曹天予认为,本体首先是指世界存在什么;其次是在某一研究领域,理论结构中不可还原的概念元素;再次是基本本体和其他基本存在之间有相互联系,但本体的存在不依赖于外在任何东西,本体是真实的、自主的存在;再次是在确定的研究领域,所有现象都可由本体推导出来,现象是本体的行为结果;最后他认为本体是有相对性的。本体的相对性主要体现在:①在分析还原中本体不可再分,是最终的成分。它客观存在,由认识能力、实验能力决定;②本体在不同概念框架,不同研究领域不能相互还原;③世界有层次结构,本体是开放的,唯一的本体不存在,只有各个领域的还原,没有大统一的理论。

(二)结构

曹天予指出,结构是一系列成分之间稳定的关系系统。一个理论的结构,分数学结构和物理结构。数学结构是自我穷尽的,结构在本体论上优先,成分只是占位者;物理结构由成份的物理性质决定,成分在本体论上优先。

曹天予理解的结构中,数学结构必须赋予物理内涵,否则没有实际意义。赋予物理内涵的结构是物理结构,物理结构由成分的物理性质决定,即由本体的物理性质决定,没有成分就没有物理结构,也就没有物理结构的实在性。通过结构,我们看到成分,看到本体,看到结构的实在性。

结构是成分之间稳定的关系系统,表明成分之间有稳定的相互作用存在,是稳定的相互作用形成了成分之间的稳定结构,相互作用建构实在论与结构实在论是相通的。

(三)建构

曹天予的"建构",是指"科学理论的结构是开放的,我们对世界实在性的认识是开放的。科学的实在性是在特定历史阶段建构出来的东西,可以修正,具有历史特征"[12]。

曹天予强调通过结构去认识本体,但又认为科学的本体具有开放性,经验证据在变化,理论结构也在变化,必然导致本体的变化。例如电子的建构就经历了汤姆逊"蛋糕模型",卢瑟福的"行星模型",玻尔的"轨道跃迁模型",量子力学的"电子云模型",量子场论的"真

空态激发模型"等等的变化。

通过结构去建构本体,结构是实在的,本体也是实在的。结构变化,本体也发生变化,本体是开放的。

三、结构实在论的三个版本

结构实在论有三个不同的版本,它们共同的目标是反对反实在论。

(一)沃热尔(J. worrall)的"认识版本"

认识版本的哲学背景是康德的"自在之物",承认本体的存在,但不可知,可知的是形式和结构。形式和结构是连续的,具有实在性。他说:"转移中有连续性或积累,但连续性是在于形式或结构,而非内容。""我们所知的是这一'形式或结构',而本体论的内容虽然还保留,但不可知。"[13]

认识版本的科学背景则以电磁场为例。电磁场理论在科学革命中,保留下来的是麦克斯韦方程的形式和结构,它是连续的,可知的,本体的内容虽在,但到底是什么尚不可知。

(二)法兰奇和雷迪曼的"本体版本"

本体版本的哲学背景是康德的"通过关系才有对象,关系是第一性的。"[14]他们认为世界只有关系和结构,物体=结构=本体。粒子和场谁最基本?波粒无法统一于同一微观客体,量子对象不可追踪,只有结构是实在的。他们说:"……本体形式的结构实在论是对本体的重新概念化,在最基本的形而上学层面,从物体变成了'结构'。"[15]

本体版本的物理背景,最根本的原因恐怕还是来源于微观客体的波粒二象性的实验事实。到目前为止,在微观世界,人们还无法合理地将波粒二象性有机地统一在粒子模型和波动模型上。他们不是去寻找波粒统一的新模型,追寻量子的形上对象,而是试图重新定义本体论概念,从而达到消解认识上的困惑。这显然是一种被动的哲学处理方法。

(三)曹天予的"知识论(或认识论)版本"

曹天予的知识论版本在第二部分已做了基本介绍。在本体论认识上,曹天予既不赞成本体不可知,也不赞成关系第一、结构就是本

体。曹天予主张通过赋予物理内涵的数学结构去认识本体，结构只是成分之间稳定的关系系统。曹天予认为成分先于结构，成分自身没有结构。我们的理解，成分就是由结构所承担的本体。与相互作用实在论中的“自在实体”属同类概念。

曹天予反对相对主义。他指出，人类的感觉印象应有一个序列，谁先谁后是公认的，这正是逻辑学产生的基础；在人类的整个知识结构中，内在的稳定性将形成对象的稳定性，这个稳定对象就是所指称的本体(成分)；事物之间普遍有联系，这将形成因果性概念。[16]我们认为，对于自然界，这种普遍联系就是四种基本相互作用，它将形成物理学中的因果关系，是物理学哲学研究对象。

曹天予认为，他的知识论版本与其他版本之不同，主要在于鼓励物理学家用物理术语来解释数学结构，用成分来理解物理结构。鼓励物理学家深入研究物理世界，发现更多的自然类，回答更多的为什么，提供现象的更多的说明。而结构实在论的其他两个版本，很可能会满意于现象学的描述。[17]

曹天予指出，科学的客观性表现为五个方面。[18]一是建构性，通过结构，建构本体；二是历史性，科学发展有历史阶段；三是整体性，承认有超出结构性陈述的东西；四是修正性，科学理论可以不断修正，结构是开放的；五是革命性，科学理论修正到一定程度，新的实验证据会引起科学革命，革命中有连续也有断裂。

四、相互作用建构实在论——结构实在论的第四版本

相互作用建构实在论与量子力学曲率解释是结构实在论家族中的一员，可称为“相互作用版本”。它与曹天予的“知识论版本”最为接近。下面将从哲学基础和科学基础两个层面加以说明。

(一)哲学基础

①在对本体的认识上，相互作用建构实在论把“本体”称作“自在实体”，这与康德的“自在之物”既有联系也有区别。联系在于：“自在实体”是指世界存在什么，它是在观察之前就已形成的“自在之物”，它是真实的、独立的存在，在约定的研究领域是最基本的概念元素；区别在于：通过由相互作用形成的理论结构，我们可认识“本体”，本体是可知的，但本体的呈现由人的认识能力和实验能力决定，也与中

介传媒的性质相联系；对世界的统一认识，我们能做的是把不同的认识层次有机地合理连接起来，不是把作用机制不同的认识层次（连续作用和非连续作用）强行归于某一层面之中。[19]这与曹天予的认识基本相同。

②相互作用建构实在论，在“自在实体”（本体）与“现象”之间引进了“现象实体”概念。“现象”指“自在之物”——本体作用于人的感官所引起的感觉表象，是事物外在的、零散的、易变的方面。它还没有系统地上升为“体”。“现象实体”是“自在实体”（本体）通过观测信号作用，由人的感官或感官的延伸与大脑神经系统综合作用，在直接建构或间接理论建构中形成的系统的、稳定的“感觉表象”。“现象实体”的提出是科学认知过程的补充，这是康德时代所无法办到的。“现象实体”可以由眼—脑系统在观察中直接建构，也可以通过现象、理论结构和逻辑推理间接建构，将“自在之物”在特定相互作用（或理论结构）中转化为“为我之物”。“现象实体”可以建构，“自在实体”（本体）通过“现象实体”给予呈现。“成分自身没有结构”，[20]“自在实体（本体）只有通过‘现象实体’才能呈现”，所以本体不能建构，但可知。

在传统本体论中，“自在实体”（本体）与“现象”是截然二分的，哲学上也可看作是本质与现象的截然二分。有了“现象实体”，主体和客体、本质和现象通过它有了相互贯通，既不是截然二分，也不是没有区别。“现象实体”是本体在人的认识中的真实呈现。

本体不能建构，本体是连续的；现象实体可以建构，现象实体是可以有区别的。反实在论者“不充分决定论旨”和“范式不可通约”中的“本体”，实际上是“现象实体”，而不是本体。反实在论者反对实在论的两条证据是不存在的。

③理论的结构是由相互作用决定的，相互作用建构实在论看似与结构实在论有区别，但实质上是一致的。有怎样的相互作用，就会有怎样的理论结构。相互作用发生质的变化，理论结构也会发生质的变化。相对论力学与牛顿力学理论结构的变化，在于观测作用中，光速从无限到有限的变化；经典力学与量子力学理论结构的变化，在于能量量子的出现，在于相互作用从连续到非连续的变化。不同的认识层次中，相互作用变了，理论结构就变了，现象实体也就变了。

本体就有了新的呈现。相互作用建构实在论作为结构实在论中的一员，揭示了结构变化的动力学成因。结构是开放的，与曹天予的结构实在论是相通的。

④相互作用是事物的真正的终极原因，每一事物通过自身体现出联系的普遍性，又通过联系的普遍性表明它自身的存在和真实性。[21]物质和物质之间的相互作用是相辅相成的，有物质，就有物质之间的相互作用，有相互作用就有物质的存在。物质与相互作用没有谁先谁后的问题。相互作用建构实在论不强化关系，虚化本体，不赞成关系第一。这与曹天予也是相同的。“现象实体”是“自在实体”(本体)的呈现，关系的“纽结”，结构的内核。

⑤相互作用建构实在论强调了人的生物建构功能。指出，“现象实体”有三种认知进路：[22](a)“自在实体”通过光等中介传媒直接作用于人的感官(主要是视觉系统)，在人脑中引起感觉表象，建构“现象实体”并由此认识“自在实体”的存在。这里从“现象”到“现象实体”的建构，再到对“自在实体”的认知，都是在人的眼—脑系统中直接一气呵成的，这是人的直接的生物认知；(b)“自在实体”向“现象实体”的转换，不能由人的感官和大脑直接认知，而是通过感官的延伸——仪器，在我们的大脑中引起感觉表象，然后再由第一种方式完成从“现象”到“现象实体”再到“自在实体”(本体)的认知过程。它与第一种认知方式的重要区别在于：“现象实体”的建构与人的理性认识有一定的外在联系，因为仪器的原理、设计依赖于人类已有知识、理论和已经建立起来的逻辑体系。(c)“现象实体”还有一种间接认知方式。那就是人不能直接感觉建构，甚至通过仪器也不能感觉建构，而是自然现象通过人的观察，由现象、已有的经验、知识、理论和逻辑基础，为研究对象建构“形象结构”。这种“形象结构”不是精神，它有“本体”依托，还有“现象”表现，是“现象实体”。如果把它作为物理学的研究对象，就是物理实体或物理实在。现象实体是本体(康德哲学)的呈现，但又不排斥经验(马赫主义)感知，它是二者的合理综合。在微观世界，对电子等微观客体的认知，我们无法通过直接观察完成生物建构，只能凭现象、经验、知识、理论和相应的逻辑推理来进行建构。建构符合客观实际的电子等微观客体的“现象实体”是人们始终追求的目标。

经验观察、实验观察最初只能得到现象。通过现象用由相互作用决定的理论结构,结合逻辑推理建构"现象实体",这个"现象实体"通过逻辑反演可以回到经验现象。逻辑首尾自洽。"自在实体"(本体)⇌现象实体⇌现象,体现了人类认识自然的全过程。它既是经验适当的,也是理论优越的。相互作用建构实在论借鉴了恩格斯、马赫、康德、笛卡儿哲学思想的精髓。

(二)科学基础

①"曲率模型"的建立

物理学上常用康普顿波长 $\lambda_0(\lambda_0=h/m_0c)$除以 2π($r_0 = \bar{\lambda}_0 = \lambda_0/2\pi$)作为静态粒子的特征长度。美国实验物理学家霍夫斯塔特对中子、质子分布半径的实验检测,及其他人对电子分布半径的测试,实验数据与特征长度均符合得相当好。[23][24]这表明用物质波波长建构电子的"形"是有实验依据的。

静态电子不是原子中的电子。静态粒子的特征长度不适用。原子中的电子在不停地运动,能级间能量是突变的,作用也是不连续的。电子从一个能级跃迁到另一个能级,我们看到的也只是光的频率和强度,是不连续的谱线。不连续的光谱不能给大脑建立一个连续的电子形象。原子中电子的德布罗意物质波波长有空间概念。类似地,我们试用原子中的德布罗意物质波波长 $\lambda_n(\lambda_n=h/p_n)$除以 2π($r_n = \bar{\lambda}_n = \lambda_n/2\pi$),即相位圆的曲率半径作为原子中能级 n 上电子的基准曲率半径(r_n)。氢原子中,这个半径 r_n 刚好可以表达成:$r_n = na_0$,n 是能级量子数,a_0 是玻尔半径,$R_n=1/r_n$ 是相位圆的曲率。氢原子及其他物质波波函数的振幅中均可分离出 $R_n=1/r_n$ 这一曲率因子。波函数的曲率表示具有普遍意义。波函数的普遍形式可简化成:

$$\psi=R_nG(x) \quad (\text{或 } \psi=R_nG(r))$$

每一个能级有一个基准曲率 R_n 与电子对应,每一个时空点有与电子对应的曲率在变化,电子波是曲率波。曲率的大小表示粒子性,曲率的变化表示波动性。波动性和粒子性在原子世界有机地统一在同一模型中。电子有了可追踪的研究对象。

曲率模型是在具体相互作用中对电子"形态"的一种建构,是结构实在论在量子力学中的模型具体化。现有量子力学与经典力学一

样，都采用质点模型。量子力学中相互作用的性质变了，理论的结构变了，但建立理论的质点模型没有变。日本的坂田昌一，法国的托姆都认为这是量子力学中产生认识危机的根本原因。[25][26]

曲率模型是对质点模型的重新改造。

②曲率解释可以包容概率解释

原子中电子越靠近原子核，曲率 R_n 越大，能级跃迁时发射的光子的频率越高；电子越远离原子核，曲率 R_n 越小，能级跃迁时发射的光子的频率越低。原子中的电子越靠近原子核，曲率 R_n 越大，“形”越小，在“形”内找到“点”电子的概率越高，电子跃迁概率越高，光越强；电子越远离原子核，曲率 R_n 越小，“形”越大，“形”内找到“点”电子的概率越小，电子跃迁概率越低，光越弱。曲率解释与概率解释有完全的、可理解的对应。曲率模型中包含有概率属性。

可以证明，我们用波长在相空间为电子建构的“形”在原子深处不可忽略，失去了宏观质点抽象的条件。[27]如果非要把原子中的电子抽象成“质点”，一方面，“点”电子的位置就会有分布误差，误差的范围就是电子“形”的展布半径，这与现今量子力学的结果完全一致；另一方面，质点必须是虚的，波是实的，这与量子场论的思想方法一致。所谓虚实，主要看动量、能量赋予谁。原子中的虚质点、实体波要想转化为宏观的实质点、虚波必须经历量子测量。量子测量是将非连续作用转化为连续作用的过程。量子场论中真空态的激发和退激，就体现为连续作用介入的量子测量过程。连续作用的介入并不是指一定要无限分割量子，被测系统的无序度增加（量子熵增加）也可以达到同样的效果。

③薛定谔方程的描述对象

相互作用建构实在论与量子力学曲率解释明确了薛定谔方程两类不同形式的描述对象。对于连续谱，与经典波动有类比性，对于非连续谱与经典波动没有可类比性。原子内部能级间能量是突变的，相互作用是不连续的，“虚质点、实体波”（曲率模型）是电子的“现象实体”，虚质点（电子）同时对应的诸多本征态（构成纯态）形成彼此独立的相干波源，而能级间量子跃迁放出固定频率的光子，预示二能级本征态之间有固定的周相差，它对应的现象是波的干涉；原子外电子受到连续作用，“实质点、虚波”（质点模型，概率分布波）是电子的“现

象实体”，本征态的连续分布（构成混合态），预示相干波源和固定周相差的消失，它对应的现象是波的共振峰（波包）。两类问题，对于线性方程，本征态作为正交基，数学处理是一样的，虽然都在相空间讨论，但物理本质不同。二者之间的转换必须有连续作用的介入，这就是量子测量的本质。曲率模型中看得很清楚，而点模型把问题搞得很模糊。“曲率模型”由物质波相位圆的曲率来定义，正好可以体现“现象实体”与相互作用的性质相关，通过逻辑反演可以回到经验现象的事实。理论是逻辑自洽的。[28]

（三）相互作用建构实在论与量子力学曲率解释的五个基本要点[29]

①提出相互作用原理。广义：指事物间的普遍联系。狭义：自然界中一切物体在时空中的“形象”和“状态”都是由物质间的相互作用形成的，既包括四种基本相互作用（引力、电磁力、强力、弱力），也包括人类观测世界使用的观测信号作用。

②区分微观作用机制与宏观作用机制。微观：能量不连续（$h\neq 0$），能级间相互作用不连续。宏观：能级连续分布，相互作用是连续的。

相互作用机制不同，“形”不能忽略，描述微观客体的“模型”亦应发生变化。

③区分微观质点与宏观质点的本质差异。原子深处宏观质点抽象原则不适用，或不能照搬。“虚粒子、实体波”（曲率模型）是微观粒子的“现象实体”。“实粒子、虚波”（质点模型）是宏观粒子的“现象实体”。

④区分量子概率与经典概率的本质不同。量子概率：有相干性；经典概率：没有相干性。前者与非连续作用相关，后者与连续作用相关。二者的转换需要经历量子测量，引进连续作用机制。

⑤揭示微观时空与宏观时空的不同属性及薛定谔方程两类描述对象的本质差异。微观：“虚质点、实体波”，“物”虚空实是基本特征，这与量子场论真空激发态思维方式相同；宏观：“实质点、虚波”（概率波），“物”实空虚是基本特征；对于连续谱，薛定谔方程描述对象与经典波动有类比性；对于非连续谱，其描述对象没有类比性。二者的转换需要经历量子测量。

总之，相互作用建构实在论，在哲学上把本体与现象的对立，改造成了本体（自在实体）—现象实体—现象相贯通，协调了本体与现

象的对立，消除了僵化的唯物主义与经验主义之间的矛盾；而量子力学曲率解释，利用曲率模型把质点模型与波动模型作了协调，把粒子—波动的对立，变成了粒子—曲率—波动的统一，消除了波粒分立造成的矛盾，解决了量子对象不可追踪的历史疑惑。现象实体与曲率模型是科学哲学与量子力学中现有矛盾协调统一的纽带。世界上没有截然对立的东西，关键是要有协调的方法，建立适当的模型。自然是和谐的，社会也是和谐的。

第三节 量子力学曲率解释的优越性

如果对几十年来诸多"量子力学解释"理论作一个大致的类型划分，大概可划为三大类：一是哥本哈根主流学派的概率解释；二是以薛定谔、德布罗意为代表的实体波解释；三是以玻普尔、布洛欣采夫为代表的系综解释。哥本哈根学派的概率解释认为，波函数 $|\psi|^2$ 代表微观粒子出现的概率密度，测不准关系表明微观客体位置和动量具有天生的不确定性；薛定谔则认为 $|\psi|^2$ 代表了微观粒子质量和电荷的密度分布，是和电磁场一样具有实体性的波动，测不准是波包的分布宽度；德布罗意对波函数的理解是粒子骑在波上，波引导粒子而行，双波（双重解）理论中，非线性解代表粒子，在中间，而线性的平面波解在周围，人们称其为"铁饼模型"，由于数学困难，深入发展缓慢；而玻普尔、布洛欣采夫则把 $|\psi|^2$ 看作是大量微观粒子的概率分布，与宏观粒子的概率分布没有什么不同，测不准关系是微观粒子位置和动量的统计弥散关系。哥本哈根概率解释承认单粒子的波动性，也为实验所证实，但却赋予微观客体天生的不可确定性，这是令人很不好接受的；薛定谔以波包描述粒子性，但波包扩散却被实验所否定；布洛欣采夫的系综解释肯定了大量粒子的概率分布，却以否定单粒子的波动性为前提，而单粒子的波动性，是为实验所证实的。

这些都是矛盾。

为了消除上述解释中的矛盾，几十年来科学家们进行了许多修正。较为成功的工作应算冯·诺依曼的量子力学公理化解释体系、玻姆的量子势解释，多世界解释和量子退相干解释。严格地说，多世界解释和退相干解释应是对冯·诺依曼的波包坍缩的进一步修正，

而冯·诺依曼解释则应是哥本哈根学派解释理论的系统化。冯·诺依曼的波包坍缩有违相对论的定域性原理，玻姆的量子势有人批评说物理意义不明确，波函数与量子势之间似乎还有循环论证，在狭义相对论层次有引进“以太”之嫌，多世界解释自以为抛弃了波包坍缩，但却赋予多世界中人的主体地位的不确定性，量子退相干解释自认为可以消除波包坍缩的非定域性，但又带来模型自身的逻辑不自洽（赵国求的分析）。总之，现有的量子力学解释尽管取得了很大的成功，但仍然有许多值得讨论的地方，“争论仍未完结”。这正是《相互作用实在与量子力学曲率解释》出现的环境基础。

依我看，一个独立的量子力学解释，必须有对波函数 $|\psi|^2$ 、测不准关系 $\Delta p \cdot \Delta x = \hbar$ 和量子测量有自己的独立诠释，而且三者之间要有逻辑一致性。哥本哈根的概率解释，薛定谔的波包解释以及玻普尔、布洛欣采夫的系综解释，对波函数 $|\psi|^2$ 和测不准关系都有自己的独立理解。而玻姆的解释中尽管有一个新的量子势（实际上德布罗意已经提出），但对波函数的新理解，又有循环论证之嫌。量子力学曲率解释对波函数 $|\psi|^2$ 、测不准关系和量子测量的理解有自己的不同认知，因此，量子力学曲率解释是一个独立于其他解释的新解释。

现在我们有条件将量子力学曲率解释与其他解释作出比较。看看量子力学曲率解释对一些疑难问题的解决是否有相应的优势。

①量子力学曲率解释认为现有量子力学的数学形式是完备的，无需作新的修正和补充。这就保证了在工具和应用层面量子力学作为唯象理论的正确性。

②按照万小龙的分析，现有量子力学解释体系，从波函数到可感物缺少对微观客体形的分析，直接从“数的元素”跳到了“可感物”，因而引起了认识上的混乱。量子力学曲率解释正好补上了这一认识过程。在原子中，微观客体的“形”不可直接观察，但可以通过物质波波长 $\frac{\lambda_n}{2\pi} = r_n$ 进行建构。r_n 为微观粒子的“现象实体”球半径。氢原子中 r_n 与玻尔半径 a_0 具有相同的意义，即 $r_n = na_0$ ，n 为能级量子数。在讨论原子问题时，微观客体“形”对所讨论问题的影响，不可忽略不计。牛顿力学中的宏观质点抽象原则，在原子世界不适用（或者不能

照搬）。这是产生量子力学解释疑难的最根本的原因。

③波函数 $|\psi|^2$ 描述原子世界微观客体“形”的变化规律，用客体的“表面曲率”表征。电子波是曲率波，曲率的大小表示粒子性，曲率的变化表示波动性。微观客体波—粒二象性的认识有了完美的统一。量子力学哥本哈根解释中的波粒矛盾在新模型中得到了很好的解决，波函数是客观的，也是实在的。玻尔的波—粒互补哲学原理不需要。

④曲率解释和概率解释可以相互转化。“形”大，“表面”曲率小，“形”内找到点粒子的可能性就小；“形”小，“表面”曲率大，“形”内找到点粒子的可能性就越大。曲率 $R(R=\frac{1}{r})$ 与“形”内找到点粒子的概率成正比例。原子中，能级量子数 $n\rightarrow\infty$，则 $R\rightarrow 0$，$\rho\rightarrow 0$。曲率解释中的波函数具有双重属性。它的一切计算的结果与量子力学概率解释完全一致。曲率解释包容了概率解释的合理部分。

⑤“测不准”不是事物的本性，而是牛顿力学中的宏观质点抽象原则在原子世界不适用（或者不能照搬）与微观客体“形”不可忽略测量造成的误差。测不准原理有实在论背景，不能作为非决定论的依据。量子力学依然是决定论的（或者叫内禀非完全决定论）。量子力学与相对论中非决定论与决定论的矛盾不存在。

⑥宏观世界与微观世界作用机制有本质的区别。微观世界的非连续作用造成能级间的突变性，是独立相干波源产生的原因。量子测量则是连续作用的介入，消去独立相干波源的过程。退相干中的量子纠缠，是测量中微观客体态的前后纠缠。微观客体的态在自纠缠中突变性消失，系统从纯量子态转化为混合态。薛定谔猫悖论自动得到解决。具有相干性的纯量子态，对应物理上态的非连续编号，而相干消失的混合态则对应物理上态的连续编号。前者对应非连续作用，后者对应连续作用。

量子测量中的“波包坍缩”不存在。测量中，突变的本征态因仪器连续作用的介入，由突变变成连续，本征态全部同时回到宏观世界（变成连续谱）。但仪器对其识别具有随机性。测量中的非定域矛盾消除了。爱因斯坦 EPR 实验中的非定域性是空间的关联，它来源于波函数的曲率特性，没有能量传递，与相对论不矛盾。

⑦人类对自然的认识离不开相互作用。相互作用原理是量子力学曲率解释的哲学基础。由此,我们提出相互作用实在论。在自然界,人类对客体"形"的认识与相互作用的性质有关。在宏观经验世界,作用的连续性让人类的眼一脑系统可以直接识别客体的"形"状,而且经验上可以认为是不变的。微观世界则不然,原子中我们通过实验现象为微观客体建构的"形"是可变的。但不同的能级有一个基本的"形"态($r_n = na_0$),对应的曲率称为基准曲率,表现在波函数的振幅中。它是实函数,是矢量的模,与波函数的复数性质及曲率的定义不矛盾。相反正是波函数的曲率属性,是矢量,才决定了波函数的复数性质。曲率可以是复平面上的矢量。概率矢量不好理解,曲率矢量是很好理解的。

⑧量子力学中物理实在要分三个不同的层面进行认识:(a)对于纯量子态,实体波和虚粒子是理论描述的物理实在,"鬼粒子"、实体波能很好地解释双缝实验;(b)对于混合态,实粒子和虚波(空波、"鬼场")是理论描述的物理实在;(c)对于经典电子论,实体的电子——质点是理论描述的物理实在。自然界中,不同的认识层次,理论描述的物理实在的表述形式是不一样的。我们不能用同一个物理实在贯穿所有的认识层次。

⑨玻姆理论中的量子势等价于曲率解释中"曲率势—空间结构",曲率势的物理意义更明确。它表示希尔伯特空间中的一种结构。曲率解释还可以对薛定谔的实体波,德布罗意波的导波,多世界解释中的多世界作出自己的对应说明,理解统计系综解释、随机过程解释的逻辑生发基础,分析它们到底丢失了什么,曲率解释有较大的包容性。

对于多粒子体系,研究表明,量子力学曲率解亦有相应的理论形式。

⑩理论的预言:(a)如果,人类能制造出具有原子内部突变作用机制的"宏观纯量子态",量子计算机的制作是可能的。否则,由于退相干带来的信息丢失,量子计算机的制作就值得讨论。(b)由于相互作用的多样性,在"自在实体"向"现象实体"的转化中,寻求构成世界单一的"元物质"及"物理实在"难以办到,但可以找到不同认识层次之间理论上的逻辑接口,并由此构成对世界的统一认识。(c)库仑

阻塞效应中，如果电子所在遂穿孔道孔径与电子的波长差不多时，库仑阻塞将失效。

参考文献

[1] 坂田昌一. 坂田昌一科学哲学论文集[M]. 安度，译. 北京：知识出版社，1987：140.

[2] 雷内·托姆. 突变论：思想和应用[M]. 周仲良，译. 上海：上海译文出版社，1989：215-280.

[3] 赵国求. 物理学与哲学之间[M]. 北京：中国新闻联合出版社，2007：47-73，75-101，129-156.

[4] 赵国求. 物理学与哲学之间[M]. 北京：中国新闻联合出版社，2007：159-170，221-235.

[5] 费因曼，C. 米勒. 今天物理学[M]. 叶悦，等译. 北京：科学出版社，1981：168-173.

[6] 赵国求. 物理学与哲学之间[M]. 北京：中国新闻联合出版社，2007：12.

[7][8] 赵国求. 量子退相干解释的再思考//中国基础科学[J]. 2006(8).

[9][11][12][14][16][17][18][20] 王巍. 结构实在论评析//自然辩证法研究[J]. 2006(11)：34-38.

[10] T. Kuhn. The Structure of Scientific Revolutions [M]. University of Chicago Press, 2nd Enlarged Ed, 1970：206.

[13] J. Worrall Structural Realism：The Best of Both World? [J]. Dialectica, 43, 1989：99-124.

[15] S. French, J. Ladyman. Remodelling Structural Realism：Quantum Physics and the Metaphysics of Seructure [J]. Syntheses, 136, 2003：37.

[19][21] 赵国求. 物理学与哲学之间[M]. 中国新闻联合出版社，2007：47-74，75-102.

[22] 赵国求. 自在实体、现象实体与物理实在[J]//自然辩证法研究. 2006(11)：39-41.

[23] 费因曼,C. 米勒. 今天的物理学[M]. 叶悦,等译. 北京:科学出版社,1981:163-168.
[24] 赵国求. 物理学与哲学之间. 中国新闻联合出版社,2007:141-143.
[25] 坂田昌一. 坂田昌一科学哲学论文集[M]. 安度,译. 北京:知识出版社,1987:140.
[26] 雷内·托姆. 突变论:思想和应用[M]. 周仲良,译. 上海:上海译文出版社,1989:208-215.
[27] 赵国求. 物理学与哲学之间[M]. 北京:中国新闻联合出版社,2007:83-85.
[28] 赵国求,桂起权. 量子力学曲率解释与波粒二象性的统一//第十三届国际逻辑、方法论与科学哲学大会报告论文集. 2007:426.
[29] 赵国求,物理学与哲学之间[M]. 中国新闻联合出版社,2007:10-23,75-103,129-159.
注:[10][13][15]转引自王巍《结构实在论评析》//自然辩证法研究. 2006(11),引文。

附录 1
光信号在时空量度中的作用

第一节　相对论时钟变慢与长度收缩

一、洛仑兹变换推导长度收缩时间延缓效应简介

推导相对论长度收缩效应采用洛仑兹变换式

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}} \tag{1.1}$$

(1.1)式表明，K′系相对于 K 系沿 x 轴正方向以速度 v 匀速运动，观察者处在 K 系中并相对于 K 系静止。

设一量杆长为 L_0，静止于 K′系且平行于 x' 轴，x_1'、x_2' 是量杆 L_0 两端点在 K′系中的坐标，x_1、x_2 是量杆运动后 K 系静止观察者同时($t_1 = t_2$)测得的量杆两端点在 K 系的坐标，则由，

$$x'_1 = \frac{x_1 - vt_1}{\sqrt{1 - v^2/c^2}}$$

$$x'_2 = \frac{x_2 - vt_2}{\sqrt{1 - v^2/c^2}}$$

得：

$$x'_2 - x'_1 = \frac{x_2 - x_1}{\sqrt{1 - v^2/c^2}}$$

故

$$\Delta x = \Delta x' \cdot \sqrt{1 - v^2/c^2} \tag{1.2}$$

(1.2)式中

$$\Delta x < \Delta x'$$

而 $\Delta x' = L_0$（量杆静止时长度），$\Delta x = L$（量杆运动后的长度），因此，在 K 系中的静止观察者看来，运动物体在运动方向上发生了

长度收缩。需要特别强调的是，此时量杆 L_0 的收缩效应只有 K 系中的静止观察者才能测量到。如果观察者跳到 K′系，则测量的是 K 系中静止量杆运动后的长度收缩。因为此时 K 系相对于 K′系沿 x' 轴的负方向以速度 v 匀速运动。当考虑 K 系相对于 K′系沿 x'轴负方向运动时，洛仑兹变换的形式为

$$x = \frac{x' + vt'}{\sqrt{1 - v^2/c^2}}$$

故

$$\Delta x' = \Delta x \cdot \sqrt{1 - v^2/c^2} \tag{1.3}$$

若 $\Delta x = L_0$ (K 系中静止量杆的长度)，$\Delta x' = L'$ (K′系中测得的量杆运动后的长度)，显然

$$L' < L_0$$

即 K′中的静止观察者同样看到了运动量杆的长度收缩。

推导时间延缓亦可用(1.1)式。仍设 K 系静止，K′系运动，运动钟固定在 K′系上。因此有

$$x'_2 - x'_1 = 0$$

由(1.1)式，有

$$x'_2 - x'_1 = \frac{x_2 - x_1 - v(t_2 - t_1)}{\sqrt{1 - v^2/c^2}} = 0$$

所以

$$x_2 - x_1 = v(t_2 - t_1) \tag{1.4}$$

根据洛仑兹时间变换式：

$$t' = \frac{t - \frac{v}{c^2}x}{\sqrt{1 - v^2/c^2}}$$

有

$$t'_2 - t'_1 = \frac{t_2 - t_1 - \frac{v}{c^2}(x_2 - x_1)}{\sqrt{1 - v^2/c^2}}$$

将(1.4)式代入，则有

$$t'_2 - t'_1 = \frac{t_2 - t_1 - \frac{v}{c^2}v(t_2 - t_1)}{\sqrt{1 - v^2/c^2}}$$

$$= \frac{(t_2 - t_1)(1 - \frac{v^2}{c^2})}{\sqrt{1 - v^2/c^2}}$$

所以 $$t'_2-t'_1=(t_2-t_1)\sqrt{1-v^2/c^2}$$

$$\Delta t=\frac{\Delta t'}{\sqrt{1-v^2/c^2}},\quad \Delta t>\Delta t'$$

此即时间延缓效应。

上述推导过程人们比较容易理解，因为观察者的地位，坐标系的运动，长度收缩时间延缓效应等概念都是清晰的。

然而推导时间延缓效应有些教科书使用的方法，有容易产生误解的地方。下面我们看看这种推导方法。

推导长度收缩效应仍用(1.1)式，而推导时间延缓效应则采用洛仑兹逆变换式[1]

$$t=\frac{t'+vx'/c^2}{\sqrt{1-v^2/c^2}} \tag{1.5}$$

当令

$$t_1=\frac{t'_1+vx'/c^2}{\sqrt{1-v^2/c^2}}$$

$$t_2=\frac{t'_2+vx'/c^2}{\sqrt{1-v^2/c^2}}$$

时，则有

$$t_2-t_1=\frac{t'_2-t'_1}{\sqrt{1-v^2/c^2}}$$

即

$$\Delta t'=\Delta t\cdot\sqrt{1-v^2/c^2} \tag{1.6}$$

习惯上对(1.6)式做出的解释是：K系中系列同步钟A与固定于K′系X′点的钟B比较，K系中静止钟A的读数Δt比K′系中钟B的读数$\Delta t'$大些。B钟运动，故运动的钟B比静止的钟A走得慢。这就是相对论时间延缓效应。

问题就出现在上述解释中。现在到底哪一个钟在运动？按照洛仑兹变换(1.5)，观察者应在K′系，并且相对于K′系中的B钟静止。K系相对于K′沿X′轴的负方向运动，因此察者应看到K系中的钟A是运动的。如果运动钟走得慢，静止钟走得快，那么，观察者应该看到K系的钟A走得慢，K′系中的静止钟B走得快。而由(1.5)式推导出的(1.6)式却表明K系中的A钟走得快，A钟静止，K′系中的B钟走得慢，B钟运动，观察者又放在K系。(1.5)式要求观察者

在 K′系，相对 B 钟静止，而由(1.5)式推得的(1.6)式的解释又将观察者放在 K 系，A 钟静止，B 钟运动，前后观察者的地位在这里是模糊不清的。这就容易造成误解。并在一定程度上增加了相对论的神秘性和人们对相对论理解上的难度。其实，我们完全可以用另一种方法，即从选用光作观测信号及动、静坐标系内时空测量单位的变化，来论证时间延缓和长度收缩效应。

二、运动钟变慢与“标准钟”记时

时间的长短总是用一周期过程来量度的。这是钟的设计原理。

为了说明运动钟走时变慢的道理，我们设计一个“标准钟”。如图 1.1，M、N 为两块平面反射镜，相距为 L_{00}，光在它们之间来回反射，往返一次算做一个记时单位，比如“1 秒”，用 τ_{00} 表示。

$$\tau_{00} = 2L_{00}/c \tag{1.7}$$

这是指放置于 x 轴上的同步的系列钟相对于观察者静止，也即相对于 K 系静止来说的，我们称为 A 钟。如图(1.1a)所示[2]。

现在假定此钟沿镜面方向(水平方向)以速度 v 向右做匀速运动，而且运动的钟称为 B 钟。如图(1.1b)。坐标系 K′就建在运动钟 B 之上，于是 K、K′系之间的时间关系符合洛仑兹变换。

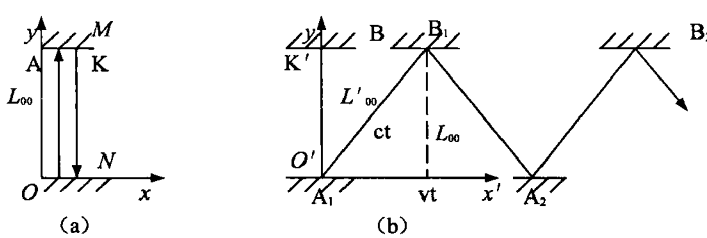


图 1.1 “标准钟”示意图

在 K 系的观察者看来，静止钟 A 记录“一秒”时间是 τ_{00}，他用 A 钟去记录一个客观事件的时间过程。设此过程的时间为 T_A，则他得到的时间读数应是

$$\begin{aligned}\Delta t &= T_A/\tau_{00} \\ &= T_A \cdot c/2L_{00}\end{aligned} \tag{1.8}$$

K 系中的静止观察者看运动的 B 钟，光往返一次的时间却长

些，因为光程 A_1B_1 走的是斜线，而且有

$$(ct)^2 = (vt)^2 + L_{00}^2$$

$$c^2t^2 = v^2t^2 + L_{00}^2$$

$$c^2t^2 - v^2t^2 = L_{00}^2$$

$$t^2 = \frac{L_{00}^2/c^2}{1-v^2/c^2}$$

$$t = \frac{L_{00}}{c\sqrt{1-v^2/c^2}}$$

对于运动的 B 钟而言（K′系），光往返一次还是一个记时单位，即为“一秒”，记为 $\tau_{00}{}'$。这个单位时间转换成 K 系的时间则是

$$\tau'_{00} = 2t = \frac{2L_{00}}{c\sqrt{1-v^2/c^2}} \tag{1.9}$$

显然，由(1.7)式动、静坐标系内记时单位之间的关系是

$$\tau'_{00} = \frac{\tau_{00}}{\sqrt{1-v^2/c^2}} \tag{1.10}$$

对前述同一个客观事件的时间过程 T_A，若 B、A 同时记录，则 B 钟记录的时间读数应是

$$\begin{aligned}\Delta t' &= \frac{T_A}{\tau'_{00}} \\ &= \frac{T_A c\sqrt{1-v^2/c^2}}{2L_{00}}\end{aligned} \tag{1.11}$$

按照我们的假设，$\Delta t'$ 是运动着的钟 B 记录的时间，或者说 $\Delta t'$ 是 K 系内静止观察者注视到运动钟 B(K′ 系) 记录的时间。Δt、$\Delta t'$ 之间的关系是

$$\Delta t/\Delta t' = \frac{\dfrac{c}{2L_{00}}}{\dfrac{c\sqrt{1-v^2/c^2}}{2L_{00}}} = \frac{1}{\sqrt{1-v^2/c^2}}$$

所以
$$\Delta t = \frac{\Delta t'}{\sqrt{1-v^2/c^2}} \tag{1.12}$$

Δt 是静系 K 内静止钟 A 记录的时间，$\Delta t'$ 是运动钟 B 记录的时间（即 K′系内的时间）。$\Delta t > \Delta t'$ 表明相对于观察者静止的钟 A 的时间读数比相对于观察者运动的钟 B 的时间读数大（与 x 轴上系列同

步钟比较）。因此，静止钟走时快，运动钟走时慢。这正是相对论要得到的结论。

通过上述分析，我们发现，运动钟走时变慢，是因为在静止观察者看来，运动钟计时单位大；而静止钟走时快，则是因为静止钟计时单位小。钟运动得越快，计时单位就越大，当 $v=c$ 时，由(1.10)式可知，计时间单位 $\tau'_{00}=\infty$，此时运动钟 B 记录的时间

$$\Delta t' = T_A/\tau'_{00} = 0$$

这就是钟慢到停的实质。这是光不能作用与它等速运动的物体造成的。它表明如果光不能与被观察对象发生相互作用，时间过程就无法计量。这正是相互作用实在论在时间概念上的体现。这时，人们想像的与实际过程联系的时间，就只有本体论意义。

三、相对论长度收缩与“标准”测长单位

前面我们分析了相对论时间延缓与计时单位之间的关系，现在我们来分析相对论长度收缩与测长单位之间的关系。在分析相对论时间延缓效应时，我们曾设计了一只“标准钟”，用光在二平面镜中来回反射一次作为计时单位。同样，在测量长度时，对应地，我们也可以用光来回反射一次所走的距离作为长度的“标准”测量单位。我们是用光来观察事物计量时空的，因此时空测量与光的特性相关。光在静系中走的是垂线，一个单位时间内走过 $2L_{00}$ 的距离（坐标系 K、K′哪个静止无关紧要），光在动系中走的是斜线，在一个单位时间内走过 $2L'_{00}$ 的距离（坐标系 K、K′哪个运动亦无关紧要）。由于光速不变，我们很容易证明“标准”测长单位 L_{00} 与 L'_{00} 之间的关系为

$$L'_{00} = \frac{L_{00}}{\sqrt{1-v^2/c^2}} \tag{1.13}$$

可见，由于光的特性，导致了 K、K′系长度测量单位发生了变化。当 $v=0$ 或 $c=\infty$ 时，$L'_{00}=L_{00}$，K、K′系测长单位相同，回到牛顿力学。

设一量杆相对于坐标系静止的长度为 L_A（L_A 平行于 x 轴），相对于坐标系静止的观察者测得的长度是

$$L_0 = L_A/L_{00} \tag{1.14}$$

坐标系 K′建于 L_A 之上，L_A 水平置于 x' 轴上。L_A 不动，K、K′

相对静止，测长单位相同，故 K′系中静止观察者测得 L_A 的长度亦是

$$L'_0 = L_A / L_{00}$$

故

$$L_0 = L'_0$$

这是量杆相对观察者静止时测量的结果。

量杆 L_A 沿 K 系 X 轴方向向右运动，钟 B 固定在 L_A 上（K′系）并与 L_A 一起运动，由于 K 系内静止观察者测量运动的 L_A 使用的测长单位变成了 L_{00}'，则他测量的运动量杆的长度应该是

$$L = L_A / L'_{00} \tag{1.15}$$

必须指出，长度测量中量杆两端的测量是同时进行的。

将(1.13)式代入(1.15)式，结合(1.14)式得

$$L = \frac{L_A}{\dfrac{L_{00}}{\sqrt{1 - v^2/c^2}}} = L_0 \cdot \sqrt{1 - v^2/c^2}$$

L_0 是物体静止时测量的长度，L 是物体运动时测量的长度，由于测量单位的变化，物体运动后在运动方向上长度发生了收缩。当 $v = c$ 时，$L = 0$，它表明与光运动一样快的物体，光不能作用于它，因而也无法认识它的空间形象。这是相互作用实在论在空间概念上的体现，空间亦回到本体论意义。

上述推导表明，相对论时间延缓和长度收缩效应，完全来自于光速不变假设（$c = \infty$ 回到伽利略变换）和光信号计时。相对论时间延缓和长度收缩效应是光速不变假设的推论。通过光速不变假设和光信号计时，将观察信号对时空记录的影响计入其中，动系和静系之间时空测量单位的变化自觉或不自觉地进入了相对论理论体系和逻辑规范之中。这是非常隐蔽的，以致在洛仑兹变换的常规推导中不易觉察。

如果我们设计的“标准钟”是原子钟，则相对于坐标系静止的原子钟是 A 钟，A 钟的计时单位是 τ_{00}；相对于坐标系运动的原子钟是 B 钟，B 钟的计时单位是 τ'_{00}，τ_{00} 和 τ'_{00} 关系是

$$\tau'_{00} = \frac{\tau_{00}}{\sqrt{1 - v^2/c^2}} \tag{1.16}$$

由于 $\tau_{00} < \tau'_{00}$，因此，同一物理过程，前者——原子钟 A 的计时

读数大，后者——原子钟 B 的计时读数小，此所谓运动钟频率变慢。此时，如果我们用光波波长作为“标准”测长单位，长度测量可做如下讨论。

根据光速、波长、频率之间的关系，原子钟静止时 A 钟有

$$c=\lambda_{00}\cdot\nu_{00}$$

式中 c 为光速，λ_{00} 是静系中光波波长，ν_{00} 是对应的频率，若 τ_{00} 是对应的周期(计时单位)，由于

$$\nu_{00}=1/\tau_{00}$$

故

$$c=\lambda_{00}/\tau_{00} \tag{1.17}$$

由于光速不变，对于运动的原子钟，同样有

$$c=\lambda'_{00}\cdot\nu'_{00}$$

式中 λ'_{00} 是动系中光波波长，ν'_{00} 是对应的光波频率，若 τ'_{00} 是对应的周期(记时单位)，也由于

$$\nu'_{00}=1/\tau'_{00}$$

故

$$c=\lambda'_{00}/\tau'_{00} \tag{1.18}$$

由(1.17)式、(1.18)式得：

$$\lambda_{00}\cdot\tau'_{00}=\lambda'_{00}\cdot\tau_{00}$$

由(1.16)式得

$$\lambda'_{00}=\frac{\lambda_{00}}{\sqrt{1-v^2/c^2}} \tag{1.19}$$

(1.19)式表明，原子钟静止时对应的光波波长小于运动时对应的光波波长。现在我们是用光波波长作为测长单位的，因此，与原子钟相对静止的坐标系内测长单位小于与原子钟相对运动的坐标系内的测长单位。

例如，若量杆静止在 x 轴方向上，且长度为 L_A，由于此时的测长单位是 λ_{00}，故测量的长度是

$$L_0=\frac{L_A}{\lambda_{00}}$$

当物体沿 x 轴方向运动时，由于测长单位变成了 λ_{00}'，故测量的长度是

$$L=\frac{L_A}{\lambda'_{00}}$$

于是 L_0、L 之间的关系是

$$L = L_0 \cdot \frac{\lambda_{00}}{\lambda'_{00}}$$

代入(1.19)式，则

$$L = L_0 \cdot \sqrt{1 - v^2/c^2}$$

若物体 L_A 在 K′系中静止，并相对于 K 系以速度 v 沿 x 轴匀速运动，则 $L_0 = \Delta x'$，$L = \Delta x$，所以

$$\Delta x = \Delta x' \cdot \sqrt{1 - v^2/c^2} \tag{1.20}$$

(1.20)式正是常见的洛仑兹收缩公式。可见，把相对论长度收缩理解为测长单位变化引起的结果与相对论的基本结论完全相符。(1.19)式中当 $v = c$ 时，$\lambda'_{00} = \infty$，即测长单位变得无穷大，此时，$\Delta x = 0$，这就是长度收缩为零的道理。上述分析表明即使用原子钟，当用光去测量与光同速运动的物体时由于不能相互作用，时空概念无法形成，因而物体给出的空间形象还是零。本体无法转换成“现象实体”。

第二节　运动钟的频率降低与运动电子的频率升高

通过前面的分析我们知道，一个运动的钟比静止时走得慢。假如此钟为原子钟，而且 ν_{00} 是原子钟静止时的频率，则此钟以速度 v 运动，频率将减少为

$$\nu'_{00} = \nu_{00} \cdot \sqrt{1 - v^2/c^2} \tag{1.21}$$

此外，根据相对论，如果把电子的静止能量 $E_0 = m_0c^2$ 同量子公式 $E_0 = h\nu_0$ 联系起来，并且把 ν_0 看作是与静电子对应的某种“波动”频率，则当电子以速度 v 运动时，按照相对论，它的质量由 m_0 增大为

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

相应的能量也变为 $E = mc^2$，此时如仍与量子公式 $E = h\nu'_0$ 相联系，则必有频率升高的结论：

$$\nu'_0 = \frac{\nu_0}{\sqrt{1 - v^2/c^2}} \tag{1.22}$$

显然运动着的原子钟频率 ν'_{00} 降低，运动着的电子频率 ν'_0 却升

高，两者产生了矛盾，原因何在？德布罗意对此有一种解释[3]。他认为运动的钟频率降低是静止观察者注视到对应于钟（原子）内部的一种场频，而运动的电子频率升高是与粒子（电子）联系在一起的某种波的频率。但是这两个场各是什么场，德布罗意没有做出明确说明。然而，根据本章提出的"时空测量单位"论却可做出明确回答。对应于原子钟内部（实则为坐标系内）的那个场，不是别的，刚好是坐标系内决定计时单位的光（电磁场）。运动钟走时慢——频率低，是因为动系内光走斜线，它有一个较大的计时单位，因此，运动的钟走时慢些；静止钟走得快——频率高，是因为静系内光走垂线，它有一个较小的计时单位，因此，静止的钟走时快些。坐标系内部有一个计量时空的场——观察信号存在！并且坐标系的运动要影响场的特性，如波长、频率的变化等。而德布罗意所说的另一个与粒子联系的波动场的频率，则是由上述计时场测量的康普顿物质波的场频。人们看到的粒子波动形象，就是由这个波场提供的。上述分析可做如下论证。

设与静电子对应有一个波动 ψ_0（实为由 ν_0、$\lambda_0=\dfrac{h}{m_0c}$ 定义的康普顿"静态"物质波），波完成一个全振动的时间过程假定为 T_A。电子静止时，静止观察者使用的记时单位是 τ_{00}，他测量此波场的振动周期是：

$$T_0=\frac{T_A}{\tau_{00}}$$

因此，电子静止时对应的波场频率是

$$\nu_0=\frac{1}{T_0}=\frac{\tau_{00}}{T_A}$$

电子运动，静止观察者再注视这个与电子联系的波动，其计量时间的单位变成了 τ'_{00}，因而与运动电子对应的波场 ψ_c（实为由 ν'_0，$\lambda_c=\dfrac{h}{mc}$ 定义的动态康氏物质波）的周期变成：

$$T'_0=\frac{T_A}{\tau'_{00}}$$

电子运动后对应的波场 ψ_c 的频率是

$$\nu'_0=\frac{1}{T'_0}=\frac{\tau'_{00}}{T_A}$$

于是 ν_0 与 ν'_0 之间的关系是

$$\frac{\nu_0}{\nu'_0}=\frac{\dfrac{\tau_{00}}{T_A}}{\dfrac{\tau'_{00}}{T_A}}=\frac{\tau_{00}}{\tau'_{00}}=\sqrt{1-v^2/c^2}$$

故
$$\nu'_0=\frac{\nu_0}{\sqrt{1-v^2/c^2}} \tag{1.23}$$

这就是(1.22)式。ν_0 是电子静止时对应的静态康氏物质波 ψ_0 的场频，ν'_0 是电子运动时对应的动态康氏物质波 ψ_c 的场频。显然与运动电子对应的康氏物质波的场频是升高了。它与运动的钟频率降低非但不矛盾，而且是互为因果的。正是因为运动钟频率降低，才出现了康氏物质波的频率升高。康氏物质波是用光记时并测量后的物质波场。

我们知道了动、静康氏物质波频率之间的关系，那么动、静康氏物质波波长之间的关系是什么？

设与静电子对应的康氏物质波 ψ_0 在一个全振动内走过的距离是 L_A，我们用原子钟的波长为单位来测量它。一个静止观察者测量与静电子对应的静态康氏物质波长，他所使用的测长单位是 λ_{00}，故与静电子对应的康氏物质波长是：

$$\lambda_0=\frac{L_A}{\lambda_{00}}$$

$\bar{\lambda}_0=\lambda_0/2\pi$ 常被理解为静电子的线度，因此，它反映的是人们对静电子空间形象的某种认识。电子运动，静止观察者使用的测长单位变成了 λ'_{00}，于是与动电子对应的物质波波长是：

$$\lambda_c=\frac{L_A}{\lambda'_{00}}$$

由(1.19)
$$\lambda_{00}=\lambda'_{00}\cdot\sqrt{1-v^2/c^2}$$

故
$$\frac{\lambda_0}{\lambda_c}=\frac{L_A}{\lambda_{00}}\cdot\frac{\lambda'_{00}}{L_A}=\frac{1}{\sqrt{1-v^2/c^2}}$$

所以
$$\lambda_0=\frac{\lambda_c}{\sqrt{1-v^2/c^2}} \tag{1.24}$$

即与运动电子对应的康氏物质波波长——康普顿波长 λ_c 小于与静电子对应的康氏物质波波长——康普顿波长 λ_0。可以肯定地

说，德布罗意所说的与运动电子对应的那个物质波就是我们定义的康氏动态物质波。它反映的刚好是与动电子对应的某种空间信息。电子运动时空间线度变小了，这正是实验的结论。

在物理教科书中证明相对论动质量与静质量之间的关系，一般是非常繁琐的。现在，如果反过来利用(1.23)式，则证明简单得多。将(1.23)式两边同乘以 h，则有

$$h\nu'_0 = \frac{h\nu_0}{\sqrt{1-v^2/c^2}}$$

而按爱因斯坦的假设 $h\nu_0 = E_{静} = m_0c^2$，$h\nu'_0 = E = mc^2$，m 为动质量，m_0 为静质量，所以有

$$mc^2 = \frac{m_0c^2}{\sqrt{1-v^2/c^2}}$$

故

$$m = \frac{m_0}{\sqrt{1-v^2/c^2}} \tag{1.25}$$

(1.25)式即为动质量与静质量之间的关系式。它表明光在时空计量中的作用与引力(体现为质量增加)在时空计量中的作用是可以转换的，或者说是等价的。由爱因斯坦假设，我们看到：物质波频率的变化与动质量 m 的变化相对应。

如果把相对论也放在相对真理的地位来考查，光信号对时当然也就只能具有相对适用性。其实从牛顿到爱因斯坦，理论上人类已经使用了两种测时信号。牛顿力学中是 $c=\infty$，相对论力学中是 $c=$ 常数。相对论物理学家可能不同意，但按照我们的哲学立场，可以提出下面推测性的观点。假如还有第三种、第四种信号可供人类建立时空概念选择，那么对时信号就可组成一数轴 u

$$\longrightarrow u$$

$u=\infty$，$u=c$ 就是牛顿力学与相对论力学的选择。相应地洛仑兹变换也就可以写成更普遍的形式：

$$x' = \frac{x-ut}{\sqrt{1-v^2/u^2}} \quad y' = y \quad z' = z$$

$$t' = \frac{t-\dfrac{ux}{u^2}}{\sqrt{1-v^2/u^2}}$$

这将为光以外对时信号的发现留下一席之地。在 $u > c$ 的对时系统中，只要 $v < u$，人类在 u 信号对时世界中，因果关系都不会遭破坏。

参考文献

[1] P. G 柏格曼. 相对论引论[M]. 周奇，等译. 北京：人民教育出版社，1962：38-40.
[2] 倪光炯，等. 近代物理[M]. 上海：上海科学技术出版社，1979：50-52.
[3] 何祚庥，等. 量子力学的丰碑[M]. 南宁：广西师范大学出版社，1994：250-268.

附录 2
测不准关系实在论背景分析

第一节　微观粒子非质点的科学依据

霍夫施塔特利用电子的“散射”实验，测量了质子和中子的尺寸。实验的成功使他获得了 1961 年诺贝尔物理学奖。霍夫施塔特实验是电子非点粒子的最有力的实验依据。[1]

霍夫施塔特实验测量表明，质子的电荷分布半径约在 1.1×10^{-15}m 的范围内，刚好是康普顿波长 $\lambda_0=\dfrac{\hbar}{m_0 c}$ $(=0.21\times 10^{-15}\,\mathrm{m})$ 数量级范围。中子似乎在一个大致等于质子尺寸的空间区域内分布着等量的正负电荷，正电荷靠近中央，负电荷处于外围。中子的康普顿波长 $\lambda_0=\dfrac{\hbar}{m_0 c}$ $(=0.21\times 10^{-15}\,\mathrm{m})$，也与中子的实测半径数量级相同。因为 $\lambda_0=2\pi\bar{\lambda}_0$，如果把 λ_0 看作圆的周长，上式表明，质子和中子的实测半径 r_0 理论上可以通过康普顿波长 λ_0 来计算。尽管人们至今还不知道电子的内部结构，但人们在粒子加速器上进行过电子电荷分布半径的测量，能量高达 60GeV 时，测得电子的半径小于 10^{-16}cm，如果考虑相对论质量效应 $\dfrac{m_0}{\sqrt{1-v^2/c^2}}$，此时的康普顿波长 $\lambda_c=\dfrac{\hbar}{mc}=\dfrac{\hbar}{m_0 c}\sqrt{1-v^2/c^2}=\lambda_0\sqrt{1-v^2/c^2}=3.2\times 10^{-16}$cm，刚好也与实验测得的电子半径数量级相吻合。有人还做过能量为 20GeV 电子对撞实验，实验测得电子电荷分布半径小于 10^{-15}cm，与

此时的康普顿波长 $\lambda_c = \dfrac{\hbar}{mc} = \dfrac{\hbar}{m_0 c}\sqrt{1-v^2/c^2} = \lambda_0\sqrt{1-v^2/c^2} = 0.965\times10^{-15}\,\mathrm{cm}$，吻合得很好。[2]看来，考虑相对论质量效应，用康普顿波长 λ_c 计算微观粒子的分布半径与实验值符合得很好。可见，人们用康氏波长 λ_0 或 λ_c 估算粒子的线度是有依据的。与静电子、中子、质子对应的康普顿波长是：

$$\lambda_{0电子} = \frac{\hbar}{m_0 c} = 3.86\times10^{-11}\,\mathrm{cm}$$

$$\lambda_{0中子} = \frac{\hbar}{m_0 c} = 0.21\times10^{-15}\,\mathrm{m}$$

$$\lambda_{0质子} = \frac{\hbar}{m_0 c} = 0.21\times10^{-15}\,\mathrm{m}$$

把康普顿波长 λ_0 作为粒子半径的理论值，理论值与实验值的比较可列成下表：

表 2.1 电子、质子、中子半径实验值与康氏波长理论值比较

$\lambda_0\lambda_c r_0 r_c$	质子(静)(λ_0)	中子(静)(λ_0)	静电子(λ_0)	动电子(20GeV)(λ_c)	动电子(60GeV)(λ_c)
理论值 $\lambda_0\lambda_c$	0.21×10^{-15}m	0.21×10^{-15}m	3.86×10^{-11}cm	0.965×10^{-15}cm	3.2×10^{-16}cm
实验值 $r_0 r_c$	1.1×10^{-15}m	1.1×10^{-15}m		$<10^{-15}$cm	$<10^{-16}$cm

由上表可见，理论值与实验值数量级符合得很好或比较好。微观粒子不是质点，并且带电微粒的电荷呈球状分布，半径 r_0(λ_0)随粒子运动速度的增加而减小。实验与理论值的比较还告诉我们：以康氏物质波波长 λ_0 为圆周的圆的半径与电子“球面”半径 r_0 有某种内在联系，也即与电子的“表面曲率”有某种内在联系。

康普顿波长 $\lambda_0 = \dfrac{\hbar}{m_0 c}$ 及相对论静能 m_0c^2 是物质实体对任何惯性系都具有的不变量，它是不可直接观察的，也就是说，它的存在与人类观不观察无关。因此，由静态康普顿物质波波长决定的粒子的半径 r_0(λ_0)及对应的康普顿“静止动量”m_0c、静能 m_0c^2，应是与

“自在实体”相对应的特征量。而 $\lambda_c=\frac{\hbar}{mc}$，$mc$ 和 mc^2（m 为动质量）是与坐标系的选择有关的物理量，它是可变的，它的存在及大小与人的观察地位及使用的观察信号有关，应是与“现象实体”相对应的特征量。霍夫施塔特对质子、中子及尔后电子半径的实验测量，均提供了可靠的实验验证。体现物质本体论不变性的康普顿动量 m_0c 和相对论静能 m_0c^2，以及由此构成的与“自在实体”对应的康氏波长 λ_0（或半径 r_0），它们紧附于“物质—本体”之上，对任何相对静止参照系都不变，但又不为人们所感知，因此，只有它们才是“不以人的意志为转移的”外在“不变之物”。所以，我们认为 m_0c 和 m_0c^2 及 $r_0(\lambda_0)$，具有“本体论”意义，并以“现象实体”的特征量——mc、mc^2、λ_c（或 mv、E_k、λ）予以呈现，“自在实体”向“现象实体”的转化，在相对论理论体系中有了科学的说明。

1930 年，朗道(Landau)等人对 m_0c 有一种解释，他认为考虑到相对论效应，即使测量一个单一的力学量，其精度在原则上也受到限制。在相对电子静止的参考系中，位置测量的不确定量为：

$$\Delta x_0=\frac{\hbar}{m_0c} \tag{2.1}$$

动量的不确定量为：

$$\Delta p_0=m_0c \tag{2.2}$$

现在知道，朗道静电子位置不确定量，正是假想中静电子“半径”r_0（Δx_0）的理论值，并由反映电子本体论特征的不变量 m_0c 决定。即：

$$r_0=\lambda_0=\frac{\hbar}{m_0c}$$

其实，朗道对 Δx_0 所作的解释，只能来源于电子的点粒子假设，而量子力学中电子刚好是质点。电子本来不是质点，具有真实的半径 Δx_0，如果把电子当成质点，那么，这个质点就必须弥散在 Δx_0 的范围之内。电子的大小 Δx_0 就成了电子（质点）可能存在的范围。于是，电子有了位置的不确定性。显然，电子位置的不确定性，是微观客体的“形”不可忽略，并对微观客体作质点抽象时赋予电子的。这就与经典力学中把物体抽象成质点时完全不同，在对电子作质点

抽象的同时，赋予了电子新的性质——电子位置的不确定性。量子力学中测不准关系赋予电子的不确定性，来源于电子的非质点特征，不能看作电子自身具有的"天生"属性。

第二节　测不准关系的实在论背景

单光子—电子碰撞是一个连续作用过程，测量后的电子处在混合态上。"实质点、虚波"是电子的"现象实体"。

海森伯单光子一电子碰撞实验，设想用 γ 光子去碰撞一个静电子，并且碰撞后电子获得的动量为 $p_{电}$（$p_{电}=\Delta p_{电}$）、能量为 $E_{电}$（$E_{电}=\Delta E_{电}$）。对光学仪器而言，根据波动论，光子的波长越短，仪器的分辨能力越高，电子的位置就测得越准确。若 $\Delta x_{电}$ 代表测量电子位置的某种误差，上述分析意味着

$$\Delta x_{电} \propto \lambda_{光} \tag{2.3}$$

光子的波长越短，光子的动量 $p_{光}$、能量 $E_{光}$ 就越大，这意味着单光子一电子碰撞中动量、能量的转移越大。即电子的动量改变量 $\Delta p_{电}$（$=p_{电}$）与光子的动量 $p_{光}$ 成正比例

$$\Delta p_{电} \propto p_{光} \tag{2.4}$$

由德布罗意关系

$$\lambda_{光}=\frac{\hbar}{p_{光}} \tag{2.5}$$

(2.3)式乘(2.4)式得

$$\Delta p_{电}\cdot\Delta x_{电} \propto p_{光}\cdot\lambda_{光}$$

将(2.5)式代入上式得

$$\Delta p_{电}\cdot\Delta x_{电}=\hbar \tag{2.6}$$

(2.6)式即为量子力学中的测不准关系式。

正统量子力学对(2.6)式的解释是：$\Delta p_{电}$、$\Delta x_{电}$ 代表一种测量精度，是动量和位置的不确定量，是测量误差。动量测准了($\Delta p_{电}=0$)，位置就完全测不准($\Delta x_{电}=\infty$)；位置测准了($\Delta x_{电}=0$)，动量就完全测不准($\Delta p_{电}=\infty$)。(2.6)式表明对动量和位置测量精度的一种限制。我们不能同时准确测量一对共轭力学量。

应该提醒注意的是：在海森伯单光子—电子碰撞实验中，正统量

子力学讲的测不准量 $\Delta p_{电}$ 实际上是电子在碰撞中获得的动量改变量，也是电子碰撞后具有的动量，即 $\Delta p_{电} = p_{电}$，因而 $\Delta x_{电}$，就是以物质波波长 $\lambda_{电}$ 为圆周的圆的半径 $r_{电}$，即 $\lambda_{电} = r_{电} = \Delta x_{电}$。

量子力学中电子是个质点，质点无大小，有确定的位置坐标。从粒子说的角度看，如果电子是质点，在单光子—电子碰撞实验中，质点与质点相碰，要么碰上，要么碰不上，碰上了就百分之百的测准了，碰不上就百分之百测不准，不存在测量误差。量子力学正统解释认定 $\Delta x_{电}$ 是位置的测不准，是测量误差，而电子又是质点，因此，作为质点力学，正统诠释必须赋予电子（质点）具有“天生”的不确定性。即作为质点的电子在 $\Delta x_{电}$ 范围内无确定行踪，具有位置不确定的内在属性。这样，在碰撞中，可能碰上，可能碰不上，碰上碰不上是随机的，取决于电子位置的不确定性，不确定范围就是 Δx。碰上的概率越大，Δx 越小；碰上的概率越小，Δx 越大；碰上的概率为零，$\Delta x \to \infty$；碰上的概率为 100%，$\Delta x \to 0$。碰上的概率当然就是电子出现的概率。这是把电子当作质点，对电子位置不确定性所做的解释。

但是，实验证明，电子不是质点。如果电子不是质点，测量中，只要非质点的光子碰上了非质点的电子，不管碰上电子的哪一部分，电子总是被测到的，并记录一个电子的存在位置。但每一个单次测量值都不能说是电子的准确位置，电子的“位置”遍布于电子自身空间形象范围之内。电子“自身”的空间分布才是单光子—电子碰撞实验中产生电子位置测量误差或位置不确定性的根源。

在相对论条件下，如果说 $\Delta x_0 = \lambda_0 = \dfrac{\hbar}{m_0 c}$ 代表静电子“动量”改变 $\Delta p_0 = p_0 = m_0 c$ 时，“自在实体”的电子某种“空间”分布，$\Delta x_c = \lambda_c = \dfrac{\hbar}{mc}$ 代表运动电子“动量”改变 $\Delta p = p = mc$（m 为动质量）时，“现象实体”的电子在闵氏四维时空中的某种空间分布，那么 $\Delta x_{电} = \lambda_{电} = \dfrac{\hbar}{\Delta p_{电}}$ 则是电子“自在实体”受到光子碰撞，因相互作用使四维时空三维空间中动量改变 $\Delta p_{电}$（$= p_{电} = mv$）时，在三维空间上同时呈现出来的粒子的“现象实体”分布范围。经典量子力学则是 $m = m_0$ 的特例形式。这个“图像”可在连续作用机制下，由物质波波长建构而成。

Δx 是四维时空中的"现象实体"在三维空间中的同时呈现。可简单证明如下：

由相对论能量公式：

$$m^2c^4 = p^2c^2 + m_0^2c^4$$

得

$$m^2c^2 = p^2 + m_0^2c^2$$

令 $p_c = mc$，$p_0 = m_0c$，$p = mv$，式中 m 为动质量，m_0 为静质量。mc、m_0c 都具有动量量纲，称作为康普顿动量和康普顿静止动量（北京大学王国文教授也给予了相同的定义）。于是有：

$$p_c^2 = p^2 + p_0^2 \tag{2.7}$$

因而，(2.7)式中 p_c、p、p_0 构成一动量直角三角形：

图 2.1 表明，实验中电子获得的动量改变量 Δp（$= p$），只是康氏动量 p_c 在三维空间中的分量，有可观察值。p_0 与三维时空垂直，它的作用在三维空间中的投影为零，属不可直接观测量。根据测不准原理：

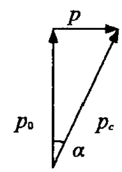


图 2.1 动量直角三角形

$$\Delta p \cdot \Delta x = \hbar$$

则

$$\Delta x = \hbar/\Delta p$$

Δx 是动量改变 Δp（$\Delta p = p$）时，"现象实体"在三维空间中位置分布的同时呈现。

而

$$\Delta x = \lambda = \hbar/p$$

是以物质波波长为周长的圆的半径，故

$$R = 1/\Delta x = p/\hbar \tag{2.8}$$

是此圆的曲率。物质波是曲率波。

将(2.7)式两边同除以 $\hbar^2$，得

$$\frac{p_c^2}{\hbar^2} = \frac{p^2}{\hbar^2} + \frac{p_0^2}{\hbar^2} \tag{2.9}$$

令

$$R_c = 1/\Delta x_c = p_c/\hbar \qquad \left(\Delta x_c = \frac{\hbar}{mc}\right)$$

$$R_0 = 1/\Delta x_0 = p_0/\hbar \qquad \left(\Delta x_0 = \frac{\hbar}{m_0c}\right)$$

结合(2.8)式、(2.9)式变为：

$$R_c^2 = R^2 + R_0^2 \tag{2.10}$$

(2.10)式中 R_c、R、R_0 构成曲率直角三角形。如图 2.2。

Δx_0 是电子“自在实体”的“曲率半径”，因此，R_0 是电子“自在实体”的“表面曲率”，与 p_0 同方向，代表四维时空中电子“自在实体”的“形象”；Δx_c 是电子“现象实体”的曲率半径，因此，R_c 是电子“现象实体”的“表面曲率”，与 p_c 同方向，代表四维时空中电子“现象实体”的“形象”；R 与 p 同方向，是相互作用中 R_c 在三维空间中的“投影”，即相对论条件下“现象实体(R_c)”在三维空间中的“同时显现”。由于

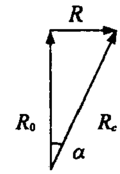


图 2.2 曲率三角形

$$\Delta x = \frac{\hbar}{p} = \frac{\hbar}{mv}$$

$$\Delta x_c = \frac{\hbar}{p_c} = \frac{\hbar}{mc}$$

而 $v \ll c$，故 $\Delta x \gg \Delta x_c$，所以物质波描述的电子的形象，类似于电子“自在实体”在三维空间中放大了的“影像”。通常，测不准关系式中的测量“误差”Δx，就是这个“影像”的分布范围。这对理解现有量子力学中 Δx 的物理意义是很有帮助的。

参考文献

[1] 费因曼，C. 米勒. 今天的物理学[M]. 叶悦，等译. 北京：科学出版社，1981：168～173.

[2] 倪光炯，等. 近代物理[M]. 上海：上海科学技术出版社，1979：172.

附录3
量子力学曲率解释实例研究

量子力学曲率解释能让量子力学回到实在论，实现爱因斯坦的梦想，并使狄拉克的预言“我认为很可能在将来的某个时间，我们会得到一个改进了的量子力学，使其回到决定论”得以实现。不过，准确地说，我们现在实现的是被称作为“内禀非完全决定论”，但这并未使狄拉克的预言打折扣。

第一节　氢原子中电子的径向曲率函数

一、氢原子中电子的基准曲率

原子中，定态本征函数对应于德布罗意驻波。如果 p_n 是氢原子德布罗意驻波的动量（也是轨道动量）[1]，且假设电子的动量 $p_n = \Delta p_n$，由测不准关系：

$$\Delta p_n \cdot \Delta x_n = \hbar$$

而

$$p_n = \frac{m_0 e^2}{n\hbar}$$

故有

$$\Delta x_n = \frac{\hbar}{\Delta p_n} = \frac{n\hbar^2}{m_0 e^2} \tag{3.1}$$

$a_0 = \dfrac{\hbar^2}{m_0 e^2}$ 是电子的 Bohr 半径，故

$$\Delta x_n = na_0 \tag{3.2}$$

当 $n=1,2,3\cdots n$ 时

$$\Delta x_1 = a_0, \Delta x_2 = 2a_0, \Delta x_3 = 3a_0 \cdots \Delta x_n = na_0$$

p_n 是氢原子各能级上电子德布罗意驻波的动量。由 $p_n = \Delta p_n$，Δx_n 刚好也是氢原子各能级上电子德布罗意驻波的波长除以 2π。

即
$$\Delta x_n = \lambda_n = \frac{\lambda_n}{2\pi}$$

我们定义 λ_n 为氢原子中能级 n 上电子的基准曲率半径。

当 $n \to \infty$ 时，$\Delta x_n \to \infty$

故由物质波波长 λ_n 给出的电子在各能级上的基准曲率分布为：

$$R_1 = 1/a_0 \quad R_2 = 1/2a_0 \quad R_3 = 1/3a_0 \cdots R_n = 1/na_0$$

当 $n \to \infty$ 时，$R_n \to 0$

可见，与电子对应的基准曲率随电子在原子中能级的增大而减小。在无穷远处，基准曲率 R_n 为零，则电子的"可视度"为零。

氢原子中，Δx_n 是电子的"自在实体"，通过电磁力的作用，在三维空间中呈现的放大图像（见附录 2），是"现象实体"的空间分布。

结论：电子在原子中的图像取决于 λ_n 形成的基准曲率 R_n，靠近原子核的基准曲率大，远离原子核的基准曲率小，无穷远处基准曲率为零。在同一能级，电子在不同时空点上的曲率变化由 $R_n \cdot G_n(x)$ 或 $R_n \cdot G_n(r)$ 决定。电子在原子核周围给出曲率的波动。

二、氢原子中电子径向波函数 $R(r)$ 与基准曲率 R_n 的关系

氢原子中尚未归一化的电子的径向波函数一般写为：

$$R(r) = (\alpha/\rho)u(\rho) = (\alpha/\rho)e^{-\frac{1}{2}\rho}f(\rho)$$
$$= \alpha B_0 e^{-\frac{1}{2}\rho}\rho^l \angle_{n+l}^{2l+1}(\rho)$$

式中

$$\alpha = \frac{2}{na_0}$$

$$\rho = \alpha r = \frac{2}{na_0} \cdot r$$

$$B_0 = -b_0 \frac{(2l+1)!(n-l-1)!}{[(n+l)!]^2}$$

$\angle_{n+l}^{2l+1}(\rho)$ 是缔合 Laguerre 多项式

故

$$R(r) = (1/na_0) \cdot 2B_0 \cdot e^{-\frac{1}{2}\rho} \cdot \rho^l \cdot \angle_{n+l}^{2l+1}(\rho)$$

$$= (1/na_0)\cdot 2B_0\cdot e^{-(1/na_0)r}\cdot[(2/na_0)r]^l\cdot\rho^l\cdot\angle_{n+l}^{2l+1}(2/na_0)r$$
$$= R_n 2B_0 e^{-R_n r}\cdot(2R_n r)^l\cdot\angle_{n+l}^{2l+1}(2R_n r)$$
$$= R_n\cdot G_n(r) \tag{3.3}$$

式中 $R_n=\dfrac{1}{na_0}$ 就是我们前面定义的电子在第 n 能级上的基准曲率。R_n 后面的函数则是我们定义的 $G_n(r)$ 。

前述思路中，氢原子径向波函数的归一化数学运算仍和原先一样。前面几个波函数归一化后的数学形式仍然是：

$$R_{10}(r) = (1/a_0)^{3/2}\cdot 2\cdot e^{-(1/a_0)r}$$
$$= (R_1)^{3/2}\cdot 2\cdot e^{-R_1(r)}$$
$$R_{20}(r) = (1/2a_0)^{3/2}\cdot(2-r/a_0)\cdot e^{-(1/2a_0)r}$$
$$= (R_2)^{3/2}\cdot(2-2R_2 r)\cdot e^{-R_2(r)}$$
$$R_{21}(r) = (1/2a_0)^{3/2}\cdot(1/\sqrt{3})(1/a_0)\cdot r\cdot e^{-(1/2a_0)r}$$
$$= (R_2)^{3/2}(2/\sqrt{3})\cdot R_2\cdot r\cdot e^{-R_2 r}$$
$$R_{30}(r) = (1/3a_0)^{3/2}[2-(4/3)(1/a_0)\cdot r+ (4/27)[(1/a_0)\cdot r]^2\cdot e^{-(1/3a_0)r}$$
$$= (R_3)^{3/2}\cdot[2-4R_3\cdot r+(4/3)(R_3\cdot r)^2]\cdot e^{-R_3(r)}$$
$$R_{31}(r) = (1/3a_0)^{3/2}\cdot(2/3)^{3/2}\cdot[(2/\sqrt{3})- (r/(3a_0\sqrt{3}))]\cdot r/a_0\cdot e^{-(1/3a_0)r}$$
$$= (R_3)^{3/2}(2/3)^{3/2}\cdot[(2/\sqrt{3})-(r/\sqrt{3})R_3]3R_3\cdot r\cdot e^{-R_3(r)}$$
$$R_{32}(r) = (1/3a_0)^{3/2}\cdot(2/3)^{3/2}\cdot(1/3\sqrt{15})[(1/a_0)r]^2\cdot e^{-(1/3a_0)r}$$
$$= (R_3)^{3/2}\cdot(2/3)^{3/2}\cdot(3/\sqrt{15})(R_3 r)^2\cdot e^{-R_3(r)}$$

上列方程中

$$R_1 = 1/a_0 \quad R_2 = 1/2a_0 \quad R_3 = 1/3a_0$$

分别表示在对应能级电子的基准曲率。

电子径向波函数的具体形式表明，不同能态的电子波函数振幅中全都包含有由 λ_n 给出的基准曲率 $\dfrac{1}{na_0}$，但波函数数学形式仍然不变。不变的数学形式使得由电子波给出的径向概率曲线与曲率曲线完全一样。

上述各状态电子径向波函数 $R(r)$ 有负值出现，如果 $R(r)$ 是概

率函数，负概率是不好理解的，因此，概率解释中必须规定 $|\psi|^2$ 与概率成比例，以保证概率为正数。但负曲率却是存在的，也很好理解。原子核周围的电子，其曲率分布在每个能级附近都有一个起伏范围，所以原子中电子的运动形象是波动变化的。同时 $R(r)$ 指出了电子的基准曲率分布与能级 n 及原子半径 r 的关系。n、r 增大，曲率 R_n 减小，n，$r\to\infty$，曲率 $R_n\to 0$。R_n 是由电场力作用决定的，因此 R_n 可称为电子的电磁性曲率。

第二节　量子力学中的一维振子

一、无限深方势阱

方阱的势能在 $(0,2a)$ 区域内有如下特点(图 3.1)。

$$U(x)=\begin{cases}\infty & x<0 \quad x>2a\\ 0 & 0<x<2a\end{cases}$$

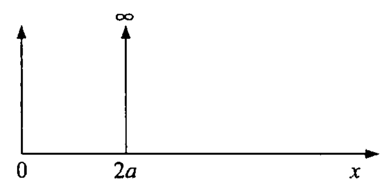


图 3.1

在 $x<0$ 和 $x>2a$ 两个区域的势能是 ∞，因此电子被关在势阱中，钻不出两侧的壁垒，所以壁外电子波函数为零，只有中间 $U=0$ 的一段可写出定态薛定谔方程：

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2}-E\psi=0 \qquad 0<x<2a$$

即

$$\frac{d^2\psi}{dx^2}+\frac{2mE}{\hbar^2}\cdot\psi=0 \tag{3.4}$$

方程(3.4)是一个二阶线性齐次常微分方程。其通解是

$$\psi(x)=A\sin kx+B\cos kx \tag{3.5}$$

其中

$$k=\frac{\sqrt{2mE}}{\hbar}$$

利用定态波函数 ψ 在 $x=0$ 和 $x=2a$ 处连续的边界条件，而且 $\psi(0)=0$，$\psi(2a)=0$ 可求得：

$$B=0,k=\frac{n\pi}{2a} \tag{3.6}$$

将(3.6)代入(3.5)得

$$\psi_n(x) = A_n \sin(\frac{n\pi}{2a})x \tag{3.7}$$

对(3.7)式进行归一化处理：

$$\int_0^{2a} \psi_n^*(x)\psi_n(x) \cdot dx = 1$$

即：

$$A_n^2 \int_0^{2a} \sin^2(n\pi/2a)xdx = 1$$

而

$$\int_0^{2a} \sin^2(n\pi/2a)xdx = \int_0^{2a} \{1/2[1-\cos^2(n\pi/a)x]\}dx = a$$

故

$$\begin{aligned} A_n^2 \cdot a &= 1 \\ A_n &= 1/\sqrt{a} \end{aligned} \tag{3.8}$$

将(3.8)代入(3.7)得

$$\psi_n(x) = \sqrt{\frac{1}{a}}\sin(\frac{n\pi}{2a})x \tag{3.9}$$

一维无限深方阱中电子的能量可通过求解含时间的薛定谔方程得到，但能量 E_n 只能取如下特殊值：

$$E_n = \frac{\pi^2 \hbar^2}{8ma^2} \cdot n^2 \quad (n = 1,2,3\cdots\cdots) \tag{3.10}$$

由德布罗意驻波知电子在对应能级上的动量是：

$$\begin{aligned} p_n &= \sqrt{2mE_n} \\ &= (\pi\hbar/2a) \cdot n \end{aligned}$$

无限深势阱中的位置测不准量 Δx ，可以理解为阱宽 $2a$ ，由测不准关系有

$$\begin{aligned} \Delta p_x \cdot \Delta x &= \hbar \\ \Delta x &= 2a \\ \Delta p_x &= \hbar/\Delta x = \hbar/2a \end{aligned}$$

此时，$\Delta p_x \neq p_n$ ，势阱的宽度 $\Delta x = 2a$ 类似于双缝实验中的缝宽 Δx ，由于 $\Delta p_x \neq p_n$ ，此时与粒子联系的基准曲率半径只能由得布罗意驻波 λ_n 求得。因

$$p_n \cdot \lambda_n = \hbar$$

故

$$\lambda_n = \frac{\hbar}{\frac{n\pi\hbar}{2a}} = \frac{2a}{n\pi}$$

但当 $n \to \infty$ 时，$\lambda_n \to 0$，这时电子表现出宏观的点粒子特性（体现为 $\Delta x \gg \lambda_n$）。电子可以从背景时空中分离出来，作质点来讨论。像双缝一样，物质波长与阱宽差不多是物质波产生的条件。
由基准曲率的定义

$$R_n = \frac{1}{\lambda_n} = \frac{n\pi}{2a}$$

于是(3.9)可写成：

$$\begin{aligned}\psi_n(x) &= \left(\frac{n\pi}{2a} \cdot \frac{2}{n\pi}\right)^{\frac{1}{2}} \cdot \sin\left(\frac{n\pi}{2a}\right)x \\ &= R_n^{\frac{1}{2}} \cdot \left(\frac{2}{n\pi}\right)^{\frac{1}{2}} \cdot \sin\left(\frac{n\pi}{2a}\right)x\end{aligned} \tag{3.11}$$

写出带有时间的定态波函数

$$\psi_n(x,t) = R_n^{\frac{1}{2}} \cdot \left(\frac{2}{n\pi}\right)^{\frac{1}{2}} \cdot \sin R_n x \cdot e^{\frac{iE_n t}{\hbar}}$$

故
$$|\psi_n(x,t)|^2 = R_n \cdot \left(\frac{2}{n\pi}\right) \cdot \sin^2 R_n x$$

可见，即使在无限深势阱中，电子波表示的也是曲率波。

二、线性谐振子

如果在一维空间内运动的电子势能为 $\frac{1}{2}m\omega^2x^2$，ω 为常数，这种体系就称为线性谐振子。双原子分子中原子之间的势能 U 是两原子间距离 x 的函数，它可以近似地看成线性振子的势能。

量子力学中，处理一维谐振子的运动，用一维定态薛定谔方程

$$-\frac{\hbar^2}{2m} \cdot \frac{\partial^2\psi}{\partial x^2} + \frac{1}{2}kx^2\psi = E\psi \tag{3.12}$$

式中

$$k = m\omega^2$$

令

$$\xi = ax, \lambda = \frac{E}{\frac{1}{2}\hbar\omega}, \alpha = \sqrt{m\omega/\hbar}$$

得方程

$$\frac{d^2\psi}{d\xi^2} + (\lambda - \xi^2)\psi = 0 \tag{3.13}$$

方程(3.13)的解是

$$\psi = \exp(-\frac{1}{2}\xi^2) \cdot u(\xi) \tag{3.14}$$

将(3.14)代入(3.13)得：

$$\frac{d^2u}{d\xi^2} - 2\xi\frac{du}{d\xi} + (\lambda - 1)u = 0$$

上方程中只有 $\lambda = 1 + 2n$ ，$n=0,1,2\cdots\cdots$才能得到物理上允许的解。也即只有能量

$$E_n = (n + \frac{1}{2})\hbar\omega \quad n = 0,1,2\cdots\cdots$$

时，ψ 才有符合实际情况的解，并且当 $|x| \to \infty$ 时解的值将趋近于零。与能量 E_n 对应的解是

$$\psi_n(x) = A_n e^{-\frac{1}{2}\alpha^2 x^2} H_n(\alpha x) \tag{3.15}$$

式中

$$\alpha = \sqrt{m\omega/\hbar}$$

$H_n(\alpha x)$ 是一个 n 次多项式，称为厄密多项式。

A_n 为归一化系数。对波函数(3.15)做归一化处理可得

$$A_n = (\frac{\alpha}{\pi^{\frac{1}{2}} 2^n n!})^{\frac{1}{2}}$$

于是(3.15)式可写成

$$\psi_n(x) = (\frac{\alpha}{\pi^{\frac{1}{2}} 2^n n!})^{\frac{1}{2}} e^{-\frac{1}{2}\alpha^2 x^2} H_n(\alpha x) \tag{3.16}$$

要对量子力学做出曲率解释，则对线性振子中波函数(3.16)也必须做出曲率解释。而要对(3.16)做曲率解释，又必须证明其振幅中含有电子在某种状态下的曲率因子，因而电子波才是曲率波。

线性谐振子的能量

$$E_n = (n + \frac{1}{2})\hbar\omega$$

故

$$\hbar\omega = \frac{2E_n}{2n+1}$$

而

$$\alpha = \frac{\sqrt{m\hbar\omega}}{\hbar} = \frac{\sqrt{2mE_n}}{\hbar\sqrt{2n+1}} \tag{3.17}$$

由于每一个能级的平衡点

$$E_n = \frac{p_n^2}{2m} + U(x)$$

令 $$U(x) = 0$$

故由动能公式得： $$p_n = \sqrt{2mE_n}$$

而(3.17)式变为

$$\alpha = \frac{p_n}{\hbar\sqrt{2n+1}} \tag{3.18}$$

由德布罗意物质波：

$$p_n \cdot \lambda_n = \hbar$$

则 $$R_n = \frac{1}{\lambda_n} = \frac{p_n}{\hbar}$$

$R_n = \frac{1}{\lambda_n}$ 即为我们定义的由动量 p_n 给出的电子在线性谐振子中的基准曲率。

故 $$\alpha = \frac{R_n}{\sqrt{2n+1}} \tag{3.19}$$

将(3.19)代入(3.16)得：

$$\psi_n(x) = \left(\frac{R_n}{[(2n+1)\pi]^{\frac{1}{2}}2^n n!}\right)^{\frac{1}{2}} \cdot e^{-\frac{1}{2}\cdot\frac{R_n^2x^2}{2n+1}} \cdot H_n\left(\frac{R_nx}{\sqrt{2n+1}}\right) \tag{3.20}$$

(3.20)式中 R_n 是我们定义的与能量 $E_n(U(x)=0)$ 对应的动量为 p_n 的电子的基准曲率，可见谐振子中的电子波，就是以曲率 R_n 为基础的波动。波函数振幅的平方也与基准曲率 R_n 成比例。波函数的相位也由基准曲率 R_n 决定。线性振子中基态电子($n=0$) 波函数的

物理意义与经典力学的矛盾也得到了消除。在 $U(x)=0$ 的平衡态，动量 p_0 最大，因而 R_0 最大，曲率最大，概率最大，有了合理的说法。速度最大，概率最小的矛盾不复存在[2]。

线性振子中的电子波能够表述成曲率波表明，量子力学曲率解释不光只对氢原子适用，对其他情况也适用。曲率解释在量子力学中是普遍适用的。对量子力学概率解释做全面而深入的改造，使其适合量子力学曲率解释是大有希望的。

由于曲率解释能包容概率解释，因而概率解释能够描述的多粒子系统，曲率解释照样可以描述。

第三节　精细结构常数 α 的物理意义

考虑电子的自旋，并考虑电子自旋与轨道运动之间的相互作用，则具有相同量子数 n 的电子的能级分裂成两个：

$$E_{n,l,j=l+\frac{1}{2}}=E_n^0+\frac{m_0c^2}{2}\left(\frac{\alpha}{n}\right)^4\frac{n}{(2l+1)(l+1)} \tag{3.21}$$

$$E_{n,l,j=l-\frac{1}{2}}=E_n^0-\frac{m_0c^2}{2}\left(\frac{\alpha}{n}\right)^4\frac{n}{l(2l+1)}$$

上述能级的分裂是产生原子光谱精细结构的原因。式中：$\alpha=\frac{e^2}{\hbar c}$，称为精细结构常数，$E_n^0$ 为第 n 能级能量本征值。

精细结构常数的物理意义是什么？人们一直不得而知。历史告诉我们，物理学上每一个物理常数的发现总是与一个新的理论相对应。如万有引力常数 G，对应牛顿力学，光速 c 的不变性带来了狭义相对论，Planck 常数 h 的发现，则产生了量子力学，而无量纲常数 g 的出现，则带来了弱电统一理论等等。因此，物理学家常把寻求精细结构常数 α 的物理意义与发现新的物理理论联系在一起。

在量子力学曲率解释中精细结构常数 α 将有明确的物理意义。

在氢原子中，以动量 p_n 运动的电子的基准曲率半径为

$$\lambda_n=\frac{\hbar}{p_n}=\frac{n\hbar^2}{m_0e^2}$$

而曲率为

$$R_n = \frac{1}{\lambda_n} = \frac{m_0 e^2}{n\hbar^2}$$

R_n 只是电磁作用产生的基准曲率，它不能代表电子的真正时空形象。因由 $m_0 c$ 确定的电子"弥漫"半径是：

$$\lambda_0 = \Delta x = \frac{\hbar}{m_0 c}$$

$$R_0 = \frac{m_0 c}{\hbar}$$

R_0 可看做电子"自在实体"的基准曲率(特征长度)。

作曲率 R_n 与曲率 R_0 之比：

$$\frac{R_n}{R_0} = \frac{\dfrac{m_0 e^2}{n\hbar^2}}{\dfrac{m_0 c}{\hbar}} = \frac{1}{n}\frac{e^2}{\hbar c} = \frac{\alpha}{n} \tag{3.22}$$

这正是精细结构能量公式(3.21)中因子 $(\frac{\alpha}{n})^4$ 的底数 $\frac{\alpha}{n}$ 。

考虑质量的相对论效应，上述结论仍成立。

$$R_c = \frac{mc}{\hbar}$$

$$R_n = \frac{me^2}{n\hbar^2}$$

式中

$$m = m_0 / \sqrt{1 - v^2/c^2}$$

作 R_n 和 R_c 之比

$$\frac{R_n}{R_c} = \frac{\dfrac{me^2}{n\hbar^2}}{\dfrac{mc}{\hbar}} = \frac{1}{n}\frac{e^2}{\hbar c} = \frac{\alpha}{n}$$

令 $n = 1$，则

$$\frac{R_1}{R_c} = \alpha \tag{3.23}$$

可见，本质上精细结构常数 α 是基态电子的经典(或相对论)"基准曲率"与"自在实体"(或相对论中"现象实体")的基准曲率之比。

"自旋"是电子自身的"一种"运动形态，是一种相对论效应。质点电子无所谓旋转，只有电子的"形"不可忽略时，才有可能考虑自旋效应。自旋在时空中才会有一定的表现。我们在第四章中已做过详

细分析，相对论时空效应就是以客体的"形"不可忽略为前提的。量子力学中，电子的"形"不可忽略，因此，自旋是一种相对论效应就十分容易理解了。有人建议与基准曲率对应，把"自旋"看成"挠率"，它是一种空间的扭曲效应。单个电子的旋涡面就像一条莫比乌斯带，环流只有沿莫比乌斯带旋转 4π 才能回到原处，刚好对应自旋 $\frac{\hbar}{2}$。因此，精细结构常数 α 在考虑电子"自旋"后的能量公式中出现也就可以理解了。精细结构常数是揭示量子力学曲率解释本质（经典质点抽象原则在量子力学中不适用）的一个常数。

我们已经证明，由相对论能量公式可求得曲率 R_n、R_0、R_c 之间的关系：

$$R_c^2 = R_n^2 + R_0^2 \tag{3.24}$$

曲率的直角三角形关系表明，R_n 对物质的广延性所做的贡献是通过非线性关系实现的。电子在无电磁相互作用时 R_n 为零，并不意味着电子不存在。$R_c = R_0$ 表明电子还有相对论静止动量 m_0c 决定的曲率，只是电磁场不存在，无法通过电磁作用在三维空间发现它而已。对三维时空而言，m_0c 是一个哲学上的"自在之物"，它在三维时空上的投影为零。

参考文献

[1] 倪光炯，等. 近代物理[M]. 上海：上海科学技术出版社，1979：172，201-202.

[2] 曾谨言. 量子力学(1)[M]. 北京：科学出版社，1995：105.

附录 4
量子力学几种主要解释的回顾与比较

在宏观世界，通常理解粒子是实物的集中形态。一个粒子在某地，它就不能同时在另一地，一地被一粒子所占据，另外的粒子就不能占据。波是实物的散开形态。一列波通过某地，另一列波同样也能通过某地，两列波在同一地点是可以叠加的。宏观世界实物不能同时既是粒子又是波，这是一个基本常识。

但是，在微观世界，人们对微观客体的观察恰好打破了宏观世界的这一禁令。例如电子，在云室里它像个粒子，但在晶格衍射时它又像是波；在双缝干涉实验中通过双缝时它像是波，而落在屏幕上时它又像粒子。微观客体是如此的不同，它将宏观世界中完全对立的两种现象集中于一身。宏观与微观世界如此巨大的不同，本质是什么？科学家们的意见分歧严重。

第一节　哥本哈根主流学派非决定论概率诠释

数学上描述微观客体波粒二重性的实验事实是容易的。海森伯的矩阵力学，薛定谔的波动力学达到了近乎完美的程度，计算与实验的精确吻合也令人惊叹。量子力学作为量子测量的一种唯象理论，对于纯物理学家在工具或实用层面或许已经足够了。但是，一个具有完美数学形式的理论还不是一个成熟的理论，成熟的理论既应有完美的数学形式，还应有对数学形式所作的诠释性原理或与数学形式相对应的合理的物理模型及对物理模型的说明。几近一个世纪，量子力学的全部诠释史，几乎就集中在认识波粒之魔的本来面目上。物理大师们费尽了脑筋，发起了多起世界性的大辩论，也未能最终达

成统一的意见。时至今日，还是给后人留下了许多必须讨论的问题。

纵观历史，量子力学数学形式体系的诠释总体看可分为两大派系，一是哥本哈根主流学派非决定论概率解释，一是薛定谔、德布罗意、爱因斯坦非主流学派决定论解释。哥本哈根主流学派认为，原子世界，波粒二重性的表观矛盾是我们的宏观描述语言受到限制所引起的。我们从日常生活经验中总结出来的语言不能够描述原子内部发生的过程或微观客体的行为。因为日常生活中，我们能够从直接经验中形成思维图景，而原子看不见摸不着，不能形成直接的思维图景，借用宏观图景来描述微观世界电子的波性和粒子性，只能是不完全的"类比"或"比喻"。对微观客体的波和粒子性，我们不能用宏观概念去理解它，表达它。但数学具有极大的抽象性和灵活性，用数学语言表达，不受日常经验限制。矩阵力学和波动力学就是这样的语言。玻恩对这样的数学语言做了一个宏观"类比"翻译。他认为，波函数 $|\psi|^2 d\tau$ 量度了在微元体积 $d\tau$ 中找到粒子的概率，$|\psi|^2$ 称为概率密度。ψ 既不代表物理系统，也不代表系统的任何物理属性，而只表示我们对系统的某种知识。这表明，波函数只具有客观性，而无实在性。在玻恩的认识中，微观粒子被"类比"为古典意义下的质点，波则是点粒子在时空中出现的概率的波动。玻恩的认识是哥本哈根学派概率解释生发的基础。

为了完善玻恩的概率诠释，实际上也就是回答为什么微观粒子在体积元 $d\tau$ 中具有统计意义，海森伯提出了一个原理，叫测不准原理。海森伯指出，在微观世界一个事件并不是断然决定的，它存在一个发生的可能性，这种不确定性正是量子力学中出现统计关系的根本原因，也是宏观语言不能描述的原由。电子波正是描述这种不确定性的，并被定量表述为概率。在海森伯看来，玻恩的知识波实际上是对微观世界事件发生的不确定性的认识。

海森伯的测不准原理后来被具体为对微观粒子位置和动量的描述。海森伯认为微观世界电子的位置和动量是测不准的，而且位置和动量的测不准符合关系式

$$\Delta p \cdot \Delta x = \hbar$$

上式中，动量测准了（$\Delta p = 0$），位置就完全测不准（$\Delta x = \infty$），位置测准了（$\Delta x = 0$），动量就完全测不准（$\Delta p = \infty$）。在微观世界

我们对粒子的"行踪"是无知的,并且这种无知植根于"天生的不确定性"。一般情况下,微观粒子既无确定的动量,也无确定的位置,电子的位置和动量只有统计意义。电子波正是描述这种统计意义的波。简言之,海森伯的微观粒子是一个天生就无确定行踪的质点,波是对电子无确定行踪的描述。显然,"不确定性"原理是海森伯为玻恩概率诠释提供的哲学基础。

玻尔对海森伯的测不准原理略有不同的理解。玻尔认为,在微观世界,一些经典概念的应用将排斥另一些经典概念的同时应用,如动量和位置、能量和时间、波和粒子等等,它们有互斥的一面,但二者又是互补的,只有其互斥的一面不能准确描述一个微观客体,必须使两者结合起来才能把关于客体的一切明确知识揭露无遗。这是玻尔试图不深究波粒二重性的物理本质,仅从实验事实角度,为微观粒子的波粒二重性提供的哲学认识。量子力学非决定论诠释遭到了爱因斯坦的强烈反对。爱因斯坦反对原子内部的不可知性,认为微观粒子不是上帝的骰子,它的行踪不靠上帝掷骰子确定。微观世界应与宏观世界一样,对物质的描述应是完全确定的,因果律在原子内部仍应成立。由于爱因斯坦始终未能建立起与量子力学形式体系相容的公认一致的确定论物理模型,爱因斯坦的认识始终处于少数派。

其实,量子力学概率解释的本质缺陷爱因斯坦是看准了的。实验表明,电子波是物理波,它有明显的衍射和干涉效应。只承认电子波是数学波,加上不可名状的"潜能"和"趋势",对粒子的控制,这就很令人费解。"不确定性"原理是那样的深奥莫测,不确定性或是上帝赋予的天生本性,或是测量仪器的测量误差,或是测量仪器在宏微观的"翻译"中走了样,如此等等,反正,人们对它的理解莫衷一是。原子内部电子的运动不可知,人们知道的只是系统的某种数学知识。玻尔的互补原理也无法解脱这一困境。承认电子身上波粒互补,对追究电子为何携波粒于一身的物理机制,实在难说说出了什么。承认互补原理,可以说是对深究电子波粒二重性的解脱。

狄拉克是哥本哈根学派的核心人物之一,但狄拉克对非决定论就非常不满意。狄拉克相信,量子力学的现有诠释不是最后的形式,总有一天,人们会回到爱因斯坦提倡的决定论。为了坚持实在论解释,冯·诺依曼建立了量子力学公理化形式体系,提出了波函数的态

解释[1]。他认为,波函数不只是量子算法系统的抽象函数,而是完全描述原子客体的状态函数。状态函数可看做希尔伯特空间的一个矢量,人们常称这为量子力学的一种几何化方法。冯·诺依曼的观点为大多数物理学家所采纳,直接将波函数称为量子系统的态函数[2],称量子系统的希尔伯特空间为态空间。如果把波函数视为态函数,量子系统就有两种不同的演化方式:

①在非测量过程中,态函数按薛定谔方程正常演化(态矢作幺正变换);

②在测量过程中,态函数发生突变,即发生所谓波函数坍缩(态矢作非幺正变换)。

波函数坍缩带来了巨大的认识困难。首先,它除了需要无限长的仪器练之外,还需要人的思维或上帝的介入。这为大多数物理学家难以接受;其次,波函数突变坍缩,预示着一种超光速通讯存在,这为相对论所不容。为了解决冯氏理论带来的两大疑难,物理学家和物理学哲学家仍在进行大量的艰苦探索。量子退相干解释就是新近的一种重要发展。

量子退相干解释承认量子理论的普适性,认为宏观客体乃至整个宇宙均可表述成符合薛定谔方程演化规律的纯态波函数。但宏观客体可以自动退相干。在微观被测系统与宏观仪器组成的总系统中,由于量子纠缠的存在和仪器的自动退相干,从仪器的状态就可以“读出”被测系统的状态。量子测量中,是仪器带着被测系统完成了退相干,实现了纯态到混合态的转化。

赵国求对上述退相干过程提出了质疑。认为“仪器带着被测系统退相干”的数学物理模型 $\psi_{总}=\sum_{n}C_n|n\rangle|e\rangle$ 有逻辑矛盾。按照宏观物体自动退相干理论,由于布朗运动式涨落和能量耗散的影响,宏观客体在极短的时间内即可完成退相干。用仪器去测量微观被测系统,将宏观仪器表述成纯量子态就只有数学意义而无物理意义。因为宏观仪器自动退相干的时间极为短暂,仪器一旦出生,就自动退相干了。实际实验中,不可能有纯态的仪器与被测系统的纠缠。若要有,要么,仪器就不能自动退相干,要么,退相干之后又得返回纯量子态,否则仪器不可能以纯态形式结合在数学模型中。这两种情形

都是有违现有量子力学基本原理的。

是不是退相干理论的上述矛盾就没有办法解决了呢？不是的。赵国求提出了一种解决方案[3]。他认为宏观仪器与被测系统的纠缠，实际上是给被测系统提供了一个连续作用机制(或外部环境)，改变了被测系统的能级突变性质。量子纠缠是被测系统自身在测量中前后状态的纠缠，状态由突变变成连续，完成了纯态到混合态的转化。这就是量子测量的实质。宏观仪器和被测系统在量子纠缠中各自自动退相干，可以避免“仪器带着被测系统退相干”带来的逻辑矛盾。

冯·诺依曼量子测量理论，承认波函数是对微观客体状态的描述，看来解决了波函数只有客观性而无实在性问题，但却没有解决微观客体的“不确定性”问题，也没有解决双缝实验中一个粒子如何同时通过双缝的问题。就我看，哥本哈根学派对量子力学的解释仍然留有许多讨论的余地。①微观客体是否真的可抽象成一个宏观的质点？而这是哥本哈根学派的一个肯定认识。②波函数描述了微观客体的状态，这个状态与微观客体本体论特征有何联系？③量子纠缠是相互作用的纠缠，还是概率的纠缠？亦或是空间的纠缠？④微观客体真的具有“天生的”不确定性？对这些问题作深入探讨，有可能加深人类对量子力学的理解。本书的讨论就是围绕这些问题展开的。

第二节　量子力学非主流学派决定论解释

量子力学诠释的另一派系是所谓的决定论诠释。它的代表人物是薛定谔、德布罗意、爱因斯坦、马德隆、玻姆、玻普尔、布洛欣采夫等人。薛定谔把电子看作实质上是一团带电物质作松紧振动的实体波，物质波完全可以像电磁波、声波那样在时空上传播，原子发光就像无线电发射机的天线发射无线电波那样容易地解释。这就排除了量子跃迁之类含糊不清的粒子概念。薛定谔在赋予 ψ 电磁意义的同时，把 $m|\psi|^2$ 当作物质密度分布，把 $e|\psi|^2$ 当作电荷密度分布，$|\psi|^2$ 被理解为“权值函数”，电的“流动行为”遵从连续性方程，电子的粒子性和波动性分别由“波包”和“密度分布”来体现。

薛氏的电磁解释面临四大困难：一是波包扩散，二是波包收缩，三是对动量和位置表象变化的理解，四是波函数多维空间困难。薛定谔完全放弃粒子图景，把电子看成一团带电物质的连续分布或一个波包实体的观点，不能被哥本哈根学派所接受。

德布罗意是决定论的又一重要代表人物。德布罗意认为，量子力学的波动方程具有两种不同的解，一个是具有统计意义的连续波 ψ 函数，另一个是奇异解。奇点构成所讨论的粒子。具有统计意义的连续解 ψ 为平面单色波，它起着导航作用，指导电子的行动。在德布罗意那里，构成物理实在的不是波或粒子，而是粒子和波。粒子和波既不是分离物，也不是有机的统一体，而是一种混和物，粒子骑在波上，波引导粒子而行。德布罗意模型中粒子骑在波上，波是什么？从哪里而来？当粒子遇到障碍或照相底片时波又哪里去了？凡此种种德布罗意难以提供任何有说服力的解释。1927 年夏，在布鲁塞尔索耳威大会上，德布罗意模型遭到了大会的否定。

量子力学决定论诠释中还有一个马德隆的流体力学诠释，这种诠释能说明一些问题，但马德隆把原子中的量子行为归结为一种非粘滞性流体在保守力作用下作无旋运动的流体行为是错误的。这种理想化的连续流体观念在原子内部显然行不通，因为这等于将一种有意无视原子性的理论用来说明原子的行为！

玻姆的量子势诠释是量子力学决定论诠释中影响较大的一派。玻姆一方面接受了爱因斯坦关于量子力学对物理实在描述不完备的观点，把探索对物理实在更精细的描述定为研究目标；另一方面采纳了玻尔关于量子现象的整体性观点，强调微观粒子对于宏观环境的全域相关性，以协调同量子力学正统理论的矛盾。玻姆的作法避开了冯·诺依曼论证的制约，只按经典哈密顿—雅可比理论的要求，将薛定谔方程变形并赋义，便顺利地提出了关于单粒子系统的量子力学因果解释。

首先，玻姆把单粒子系统的波函数写成指数形式：

$$\psi = R(r,t)\exp\left[-i\frac{S(r,t)}{\hbar}\right] \tag{4.1}$$

式中 $R(r,t)$、$S(r,t)$ 为实值函数。将(4.1)代入薛定谔方程：

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + U\psi \tag{4.2}$$

方程中 m 为粒子质量，U 为经典势，并分离变量即可得到哈密顿—雅可比方程

$$\frac{\partial S}{\partial t}+\frac{(\nabla S)^2}{2m}+U+Q=0 \tag{4.3}$$

和位形空间中粒子概率密度 $\rho=R^2$ 的平衡方程

$$\frac{\partial\rho}{\partial t}+\nabla\cdot\frac{\rho\nabla S}{m}=0 \tag{4.4}$$

(4.3)式中的 Q 是

$$Q=-\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R} \tag{4.5}$$

玻姆称之为量子势。玻姆认为(4.3)和(4.4)两式启示人们：在微观领域，微观粒子具有实在论意义。即理论中的粒子应视为实实在在的连续运动着的粒子，它具有动量 $p=\nabla S$，不仅受经典势 U 的作用，还受到量子势 Q 的作用。玻姆认为，量子势的存在是经典理论与量子理论之间差别的主要原由。量子势与薛定谔波函数 ψ 有关，任何具体情形，都由薛定谔方程的实际解确定。方程(4.3)使粒子具有连续径迹运动行为，而方程(4.4)又使粒子在量子力学中的统计预示成为可能。玻姆指出，量子势因果解释中，波函数有双重意义：第一，它表征常规意义中的玻恩概率波函数；第二，它确定非定域作用在粒子上的量子势。波函数表征与经典场有本质区别的实在场。后来玻姆称这种场为量子信息场。

玻姆理论的关键是他的量子势，而量子势仅依赖于形式

$$Q=-\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}$$

因此，即使这个波由于大距离传播而扩散开来

$$|\psi|^2=R^2\to 0$$

量子势也可能仍有很强的效应，即

$$\frac{\nabla^2 R}{R}\neq 0$$

例如，当波通过双缝时，其干涉图样会产生一个复杂的量子势，它可以对远离双缝的粒子施加影响，使粒子在屏上的分布遵从概率密度方程。

有人对玻姆量子势理论进行计算机模拟，不仅双缝实验，而且在

AB效应、势垒穿透和势阱散射等情形中，理论与实验都有很好的吻合。

玻姆的量子势理论在多粒子系统中亦有很好的应用，只是此时量子势：

$$Q=-\frac{\hbar^2}{2m}\sum_{i=1}^{N}\frac{\nabla^2 R(r_1,r_2\cdots r_N,t)}{R(r_1,r_2\cdots r_N,t)} \tag{4.6}$$

式中 $R(r_1,r_2\cdots r_N,t)$ 为 N 粒子系统波函数 $\psi(r_1,r_2\cdots r_N,t)$ 的实幅部分。

玻姆的量子势诠释是决定论诠释派系中影响较大的分支。玻姆认为他的量子力学哈密顿—雅可比方程，通过经典势 U 和量子势 Q 确定了粒子在经典概念下的连续径迹运动，位形空间中的概率密度平衡方程使得量子力学的统计预示成为可能。在玻姆的理论中，作为质点的粒子，其运动具有经典的轨迹，并由其哈密顿—雅可比方程描述，但对于一个具体的粒子，它走哪一条通道却是随机的，每个通道中粒子密度的变化宏观上遵从概率密度平衡方程的描述。玻姆的量子势诠释取得了很大的成功，几乎所有的量子力学实验它都可以合理解释，但是由于量子势来源不清，也没有量子势依托的哲学基础，更由于爱因斯坦认为他复活了以太假说，尽管玻姆本人认为量子势可解释为原子内的自组织力，但玻姆的量子势诠释还是被冷落在正统诠释之外。洪定国教授认为这一现状近年来有比较明显的改观。

更深入的分析，波函数与量子势之间似乎还有循环论证之嫌。因为量子势由波函数的具体形式决定，而波函数又由包含量子势的运动方程的解决定，这就是一种逻辑循环论证。

玻姆的量子势概念的缺陷是物理意义不明确，也缺少相应的哲学背景，并有循环论证和引进以太之嫌。

如果把玻姆波函数的形式

$$\psi=\mathrm{R}e^{-i\frac{S}{\hbar}}$$

理解为曲率解释中的曲率函数，那么玻姆量子势的物理意义就很清楚了。量子势：

$$Q=-\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}$$

中的 R,正包含有我们定义的曲率因子。量子势反映了电子运动过程中自身空间结构的变化,正是空间结构的这种变化,决定了“点”电子运动的状态。量子势就是曲率“势”。曲率势不是以太,而是“空间是物质的延展性”哲学思想的物理化,它不包含有能量的传播。电子本来不是质点,当把电子抽象为质点之后,作为数学处理方法,电子的形象转化成了曲率“势”。曲率大的地方,则是电子动量大或出现概率大的地方,反之亦反。

上述种种是量子力学决定论派系主要人物的观点。爱因斯坦反对非决定论,赞成决定论,但爱因斯坦的基本思想是系综说。由于系综说不承认单个粒子的波动性,被双缝干涉实验所不容,尽管爱因斯坦反对非决定论是有力的,但由于他始终没有提出一个令人信服的决定论诠释模型,又无法将决定论派系拧成“一股绳”,到目前为止量子力学诠释领域仍然是非决定论的天下。

第三节 量子力学统计系综解释

一、玻普尔、布洛欣采夫的统计系综解释

自从 1927 年在第五届索尔维会议上提出了量子力学的统计系综解释后,爱因斯坦就一直坚持这种观点。他坚持认为,“ ψ 函数所描述的无论如何不能是单个体系的状态,它涉及的是许多体系,是统计力学意义上的“系综”。但是,爱因斯坦涉及较多的是统计系综解释的必然性问题,而没有具体阐述这种理论的物理内容。

在 20 世纪 30 年代,玻普尔提出了海森伯的测不准关系的统计系综解释。根据这种解释,测不准关系仅仅表示所包含的参量之间的统计散布关系。即一定的粒子聚合体(在物理分离的意义上),如果在某一瞬间聚合体的位置弥散为 Δx ,则它们的动量 p_x 也显示出随机弥散,其散布范围为 Δp_x ,并且 $\Delta p_x \cdot \Delta x \geqslant \hbar$ 。在玻普尔看来,量子力学的哥本哈根解释颠倒了测不准关系与量子论的统计学解释之间的逻辑关系[4]。希尔伯特空间中矢量提供的是统计性断言,不是关于单个粒子行为的精确预示,量子力学的问题本质上是统计问题。“所有的反对问题和几乎所有现存困难都来源于对概率论的误

解。"因而"对量子力学解释来说，最迫切需要的是对概率论的解释问题。"在 1953 年独立提出的量子力学统计系综解释中，玻普尔将"概率"诠释为一种"倾向性"，一种附属于进行重复测量的整个实验装置，概率是一种介于现实性和可能性之间的物理实在。

玻普尔对量子力学和物理学理论的主要观点可概括如下[5]：

①量子力学像牛顿力学，玻尔兹曼的气体理论一样，包含客观的、实在的性质。

②量子力学本质上是统计的理论，它并没有超出经典物理学的任何新的认识论意义。同量子力学一样，经典物理学也是非决定论的。整个物理学都是非决定论的，统计性原则上是整个物理学的基础。

③量子力学解释中几乎所有现存困难，都来源于对概率论的误解，尤其是来源于物理学中自拉普拉斯至马赫、爱因斯坦及现今业已存在的对概率进行主观主义解释的古老传统，以及对相对的或条件概率计算的忽视。所以，哥本哈根学派不得不在概率的主观主义解释和客观主义解释之间摇摆。

④通常解释中的不确定关系没有任何特殊的认识论意义，它并不表征某种对我们的知识的局限性，它们只是一种统计的散布关系，海森伯对测不准关系的解释是错误的。

⑤迄今为止，波与粒子之间的关系还未得到充分的探讨，波与粒子之间的二象性，是一种不负责任的说法；波与粒子之间并不具有"互补性"的特征，"互补性"不应是一种科学理论应具备的特征，它最多是一种意识形态。我们应该放弃"互补性"这个概念。

⑥量子力学不是一个超距作用的理论，"波包收缩"不是量子理论应有的效应特征，它是某种在任何概率理论中都会发生的事件。

布洛欣采夫在他的《量子力学原理》(1949 年版)中，第一次给量子系综下了这样的定义：系综是从属于同一客观环境的"粒子(或体系)的集合"。这个定义受到了福克的批判。1963 年布洛欣采夫对量子系综概念作了重新表述。在他看来，由于作用量的量子性，闭合的弧立的微观系统是不存在的。任何微观客体 u 总是处于一定的宏观环境 M 中，并且一般说来，这一宏观环境 M 与观测仪器 m 也是不可分割的。所谓"量子系综"就是这些大量相互独立的 M+u+m 组

成的总和。在量子系综的观念中,"量子的统计性是微观与宏观环境相互作用的结果",波函数"确定着原子对一定宏观环境的从属性。"

在他的测量理论中,布洛欣采夫把测量仪器看作量子系综的谱分析器,它根据仪器的本性,从给定的系综中选出一些子系综来。这样的一个子系综各自具有一个新的波函数,这相当于通常所说的"波包收缩"。"在物理上,波包收缩意味着一个粒子在测量之后从属于一个新的系统"[6]。

玻普尔把整个物理学都划入非决定论,看来有些偏激。因为牛顿力学中的统计行为具有决定论基础是肯定无疑的。初始条件的无法把握是牛顿力学中统计行为的根本原因。统计系综解释,把量子力学中的统计行为看作与热力学完全一样,这无疑是混淆了非连续作用机制与连续作用机制的根本区别,忽视了量子测量在机制转换中的作用。

二、随机过程解释

量子力学的随机过程解释,是力图通过研究薛定谔方程,海森伯关系式同扩散过程或布朗运动理论中的方程之间的相似性,将量子力学解释为一种关于概率过程或随机过程的经典理论。经典与量子在概念结构上是同构的,因而对经典物理学概念的任何摒弃和背离都是不必要的。1931 年 3 月 12 日,薛定谔在呈交给柏林科学院的一篇论文中,首先发现了存在于波动方程与扩散方程

$$D\frac{\partial^2 w}{\partial^2 x^2}=\frac{\partial w}{\partial t}$$

(其中 $w(x,t)$ 是粒子的概率密度,D 为扩散常数)之间的相似性,即若已知 $w(x,t_1)$ 和 $w(x,t_2)$,那么在时刻 $t(t_1<t<t_2)$ 的分布概率与量子力学概率密度的表示式 $\psi\psi^*$ 极为相似。经典概率理论与波动力学之间的这种数学相似性是导致人们对随机过程解释感兴趣的最直接的原因。

1933 年,弗斯证明了海森伯关系式在随机过程方面也存在类似物。弗斯发现,对于作一维运动的自由粒子,不仅薛定谔方程在随机过程方面有类似性,而且关于位置与动量不确定关系式在随机过程方面也存在类似性。

弗斯首先用统计方法导出了海森伯关系式，然后，他定义了扩散过程的位置不确定度。由于每个粒子的运动是别的粒子无规则碰撞的结果，这个不确定度随着时间而线性增大。他先定义扩散流 Q，即单位时间内单位面积的扩散量，再定义 Δx 与 Δv，弗斯由此得到了与海森伯关系式相似的关系式 $\Delta x \Delta v \geqslant D$。

弗斯的这一发现，对于随机过程解释来说具有非常重要的意义。上世纪 50 年代玻普尔提出的量子力学统计系综诠释，就是建立在随机过程之上的相似诠释。

随机过程解释，后来经保加利亚的达泽夫、美国的内尔逊、波兰的加尔琴斯基及墨西哥的德拉佩尼亚——奥埃巴赫等人的发展，变成了一个世界性的研究课题，使随机过程解释在数学上有了相当深入的发展，尤其是德拉佩尼亚——奥埃巴赫 1970 年还将随机过程解释扩展到了无旋粒子以及自旋为整数或半整数的粒子的随机过程，并对它们作了相对论表述。

由于达泽夫对随机过程解释的发展需要引进物理场的承担者，因而，量子力学随机过程解释忽视非连续作用机制并将微观粒子描述成作某种布朗运动，都会涉及到粒子同类似于“以太”的相互作用问题，因而也就牵涉到了假想实体的存在问题。在目前，由于对类似的“以太”缺乏经验支持，随机过程解释在哲学上不能令人满意。

三、艾弗雷特的多世界解释

多世界解释由艾弗雷特首创，以后又经过惠勒、德威特、格拉汉等人作了发展。量子力学多世界解释又称为 EWG 理论。多世界解释旨在寻求一种量子力学诠释体系，它不仅要消除对经典的（宏观的）观察装置或外部（最终的）观察者的需要，而且还要消除对形式体系作先验的操作解释的需要。这一理论的独特之处在于，EWG 明确宣布，那种认为物理世界在许多宏观可能性（含于展开式之中）中作出一个具体选择的看法，只不过是一种幻觉；这些可能性是全部实现了的，根本没有发生什么波包扁缩。EWG 认为，整个宇宙分裂为两个或更多个彼此独立的“世界”，在其中的任何一个世界中都有一种可能的实验结果得以实现。

根据艾弗雷特的阐述和德威特的总结，量子力学多世界解释的

基本点可概括如下：

①量子力学的数学形式体系是完备的，不需要给它增添任何形而上学的内容。

②不需要引入外在的观察者。

③谈论整个宇宙的态矢量具有物理意义，宇宙态矢量的概念在物理学上是必要的。

④这个态矢量从不坍缩，作为整体的宇宙遵循严格的决定论。

⑤尽管实验观测装置的各态历经特性得到了量子力学统计解释内在一致性的严格保证，从根本上说，这一特征并不是绝对必要的。

⑥不需要对量子力学的形式体系作先验的操作解释，统计解释不再被认为是先验的，多世界解释与通常解释之间是元理论与理论的关系。

⑦分立的经典实在是不存在的，我们必须对通常的实在观念作彻底的变革。宇宙本是一个观察者参与着的宇宙。

在量子力学形式体系中，包含着5个公设：态函数公设；力学量公设；测量值公设；时间演变方程公设和多体全同性公设。艾弗雷特对正统量子力学的修改是从第三公设开始。为了理论的自洽，他对波函数(态函数)的定义也作了相应调整。整个宇宙的波函数称为“宇宙波函数”。宇宙波函数中既包含观测者和各类测量仪器，又包含被测对象。于是，在多世界解释中既不需要旁观的观测者，也不需要导致宇宙波函数坍缩的“上帝”。

在量子力学通常解释的第一公设中，还包含态叠加原理，即当$\psi_1,\cdots,\psi_n$是体系处于ψ的态时，它同时也部分地处于$\psi_1,\cdots,\psi_n$态中。艾弗雷特在多世界解释中，将原先正统量子力学中的“状态”换成了各种可能的“世界”；相应的“态叠加原理”到了多世界解释中就成了“世界叠加原理”。即当体系处在世界$\psi=\sum c_n\psi_n$中时，它同时也部分地处于世界$\psi_1,\cdots,\psi_n$中。多世界解释意味着，当猫有等量机会成为“活猫”或“死猫”时，宇宙波函数就分裂成两个世界分支；其中一个世界中猫是活的，同时这个世界中观测者看到“活猫”；而另一个世界中猫是死的，同时该世界中观测者看到“死猫”。

对多世界解释的批评有四点：①它依然是线性非定域的，而这种非定域性很容易由玻姆的量子势得出；②多世界解释假设宇宙分裂

出现的实际点，就是作出测量的点，但是什么是一次"准确测量"却无法交待清楚。EWG 无法说清波函数，可观测量和经典极限的真正含义，无法说清"量子引力"场的涨落，包括"真空涨落"和"时间涨落"。此外，多世界解释的时间可逆性同测量历史的不可逆性也有矛盾；③多世界解释有滥用数学的现象，引入了远离现象世界的"其他世界"；④物理学家们大多喜欢使用"可能性"等表述方式，而不喜欢"多世界"之类的表述，EWG 解释中的其他世界对我们来说是不可观察和不可交流信息的，因而纯粹是一种理论虚构。

参考文献

[1] 洪定国. 物理实在论[M]. 北京：商务印书馆，2001：214.
[2] 洪定国. 物理实在论[M]. 北京：商务印书馆，2001：203.
[3] 赵国求. 量子退相干解释的再思考 // 中国基础科学[J]，2006(8).
[4] M. 雅默. 量子力学哲学[M]. 秦克诚，译. 北京：商务印书馆，1986：526-532.
[5] 曹志平. 没有完结的争论——关于量子力学解释的历史与哲学[M]. 长沙：湖南科学技术出版社，1999：12-20.
[6] 赵国求，桂起权，等. 物理学的新神曲[M]. 武汉：武汉出版社，2004：85.

附录 5
相关名词翻译

一、科学家

Albert Einstein 阿尔伯特·爱因斯坦
Alfred Lothar Wegener 威格纳
Aristotle 亚里士多德
Arthur Holly Compton 阿瑟·霍利·康普顿
B. Podolsky B. 玻多尔斯基
Benedictus Spinoza 斯宾诺莎
Blaise Pascal 布莱士·帕斯卡
Dmitri Blokhintsev 布洛欣采夫
Tian Yu Cao 曹天予
Claudius Ptolemaeus 托勒密
David Bohm 戴维·玻姆
David Hilbert 大卫·希尔伯特
De Finnerty 德·芬内蒂
Democritus 德谟克里特
Ernest Rutherford 卢瑟福
Ernst Mach 马赫
Erwin Schrodinger 埃尔温·薛定谔
Euclid of Alexandria 欧几里德
F. W. Nietzche 尼采
F. G. Bruno 布鲁诺
Fallange 法兰奇
Francis Bacon 弗朗西斯·培根
Friedrich Engels 弗里德里希·恩格斯
G. W. F. Hegel 黑格尔
Galileo Galilei 伽利略
H. Everett 埃弗雷特
Harman 哈曼
H. A. Lorentz 洛仑兹
Hermann Minkowski 闵可夫斯基
Hoffstadt 霍夫斯塔特
Immanuel Kant 康德
Isaac Newton 牛顿
James C. Maxwell 詹姆斯·麦克斯韦
John S. Bell 贝尔
John Dalton 约翰·道尔顿
Joseph John Thomson 汤姆逊
Joseph Louis Lagrange 约瑟夫·拉格朗日
Karl Popper 卡尔·波普尔
L. Landau 朗道
Liné De Vries 利纳·德弗里斯

Louis de Broglie 路易斯·德·布罗意
Madelung 马德隆
Max Born 马克斯·玻恩
Michael Faraday 法拉第
N. Rosen N. 罗森
Nicolaus Copernicus 哥白尼
Niels Bohr 尼尔斯·玻尔
Paul A. M. Dirac 保罗·阿德里·莫里斯狄拉克
Pierre Gassendi 伽桑迪
Pythagoras 毕达哥拉斯
R. Brown 布朗
R. Mills 米尔斯
Rediman 雷迪曼
Rene Descartes 笛卡儿
Rene Thom 雷内·托姆
Richard Philips Feynman 费因曼
Riemann 黎曼
Roger Penrose 彭罗斯
Rudolf Carnap 鲁道夫·卡尔纳普
Savici(罗), Savicj(南)萨维奇
Shoichi Sakata 坂田昌一
Thomas Kuhn 托马斯·库恩
Vladimir Lenin 弗拉基米尔·列宁
Van Frassen 范·弗拉森
Von Neumann 冯·诺依曼
W. H. Zurek 朱瑞克
Waller 袄勒尔
Werner Karl Heisenberg 韦纳尔·卡尔·海森伯
Wilflid Sellars 塞拉斯
Yang Cheng Ning 杨振宁

二、哲学

absoluteness 绝对性
absolute space 绝对空间
absolute 绝对
abstract 抽象
accidental relations 偶然关系
actionless 静止的
air, gas, ether, vital force 气
ancient Taoist religion philosophy 古代道教哲学
a perverse trend, an evil influence 邪气
apparition-soul, ghost 幽灵
appearance 现象
appear, show, manifest oneself 显现
appellation, title 称谓
attributum 属性
basic interaction 基本相互作用
basic relations, basic connection 基本联系
becoming evolution 生成进化
being 存在
benefit gas, healthy trend 好气
Bestandigkeit(德) 持续性
causal determination 因果决定性
causality 因果关系

cause 原因
Chinese traditional philosophy 中国传统哲学
coacervation,conglomeration 凝聚
cognitive version 认识版本
cognitivism 认识论
compatibility 自恰
composition, component part, ingredient 成分
concept 概念
concrete form 具体形式
condensantion state, condensed state 凝聚态
consciousness,conscience 意识
constructionalism, construction theory 构成论
constructive realism of interaction 相互作用建构实在论
construct 建构
contradiction 矛盾
corporeal structure 有形结构
cosmic 宇观
course of cognition 认识进路
critical philosophy 批判哲学
determinism 决定论
dialectics 辩证法
ding an sich(德), being-in-itself, thing-in-itself 自在之物
ding für sich(德), thing-for-us 为我之物
dominant connection 主要联系
dualism, binary theory, dualistic theory 二元论
duplicate 复写
epistemological version 知识论(认识论)版本
equal in value, of equal value 等价
equal rights 平权
essential element 要素
essential link 本质联系
eternal being, yu (Being) 有
even state 平衡状态
experience 经验
extension of substance 物质的广延性
extensive distribution 广域分布
external connection 外部联系
false appearence, pseudomorph, virtual image 假象
final cause 终极原因
flatness,even,homogeneous 均匀,平直性
form of physical object 物体的形状
from nothing comes being 无中生有
from quantitative changs to quanlitative changs 量变到质变
gas mixture 合气
Gedanken(德) thinking, thought 思维
general principle of interaction

广义相互作用原理
general 广义
ghost 鬼
Haken's demon 哈肯妖
harmonious 和合
hidden-variable 隐变量
image 形象
imcomplete determinism, subdeterminism 非完全决定论
immaterial tao 道无形
immediate connection 直接联系
immeditate perception experience 直觉经验
implicit existence being, noumenon 本体
indeterminism 非决定论
inequal in value 不等价
inequal rights 不平权
influence each other 相互影响
inherent attribute 固有属性
inner interconnection 内部联系
interaction mechanism 作用机制
interaction 相互作用
interiorization, internalization 内在化
intrinsic subdeterminism, intrinsic imcomplete determinism 内禀非完全决定论
irreductive patten 范式不可通约
irreversible 不可逆
isolate 孤立的
Jin's demon, Jin's psychic being 金妖
knowledge 知识
Laplace's demon 拉普拉斯妖
law, regularity 规律性
level of cognition 认识层次
local 定域
logical chain 逻辑链条
logical circular reasoning 逻辑循环
logical common patten 逻辑通式
logical contradiction 逻辑矛盾
logical convention 逻辑约定
logical inference 逻辑推理
logical interface 逻辑接口
logical inversion 逻辑反演
logically compatible 逻辑自恰
logical universal coupling 逻辑万向节
logic 逻辑
macroscopic, macro- 宏观
materialism philosophy 唯物主义哲学
materialism 唯物论
materialism 唯物主义
mathematical structure 数学结构
matter structure 物质结构
Maxwell's demon 麦克斯韦妖
meaning 意义
mediate connection 间接联系
metal, wood, water, fire and earth 金、木、水、火、土
micro- , microscopic 微观

monism，Einheitslehre（德）一元论
natural world 自然界
necessary connection，necessary connexion，necessary relations 必然关系
non-essential link 非本质联系
nonlocal 非定域
nonsufficient determinism 不充分决定
oberserve 观察
objective reality 客观实在
object 对象
object 客体
ontological imcomplete determinism，ontological subdeterminism 本体论不完全决定论
ontological version 本体版本
original being，primal being 本原
original quality，essence 本质
paradox 悖论
paradox 佯谬
perceive 感知
perception 知觉
perceptual experience 感官经验
philosopher 哲学家
philosophical speculation 哲学思辨
philosophy 哲学
physical image 物理图景
physical object 物体
physical reality 物理实在
physical structure 物理结构
physical substance 物理实体
possibility 可能性
potentiality 潜能
primal fluid，animal spirits，yuan-chi 元气
primary qualities 第一性
primary substance，prima mataria 元物质
principle of interaction 相互作用原理
probabilty，chanciness 或然性（偶然性）
process of cognition 认识过程
random，randomness 随机性
real appearance 真象
realism 实在论
reality，being 实在性
reality 实在
reality 现实
real masspoint 实质点
real partical 实粒子
reasoning in a circle，diallelon，diallelus 循环论证
reductionism 还原论
reflection 反映
relation 关系
relativeness 相对性
relative space 相对空间
relative 相对
research object 研究对象
restrict each other 相互制约

reversible 可逆
saltus, leap 飞跃
science of thinking, science of thought 思维科学
scientific anti-realism 反科学实在论
scientific realism 科学实在论
scientific view of space-time 科学时空观
secondary connection 次要联系
sensory organ 感官
sensuous representation, sensible presentation 感觉表象
simultaneous 同时性
'space-time image' of physical object 物体的"时空形象"
space-time image 时空形象
special principle of interaction 狭义相互作用原理
special 狭义
subjective mind, subjective consciousness 主观意识
subject 主体
substance-in-itself 自在实体
substance ,matter 物质
substance of apperance, phenomenological substance 现象实体
substance 实体
substance 物质本体
substantial wave 实体波
superiorty,advantage 优越性
surface specific property 表面特征
system 系统
tao-fa-tsu-jan 道法自然
tao, truth, principle, way 道
the demon of becoming-to-be 生成妖
theology 神学
theoretical structure 理论结构
the primacy of matter 物质第一性
the primacy of the will 意识第一性
the theory of coming-to-be 生成论
the truth wing 真理派
trend 趋势
twist of relation 关系的"扭结"
universal connection 普遍联系
universal 普遍性
value 价值
view of absolute space-time 绝对时空观
view of relative space-time 相对时空观
view of space-time 时空观
view of universe, philosophical view of the world 世界观
virtual mass point 虚质点
virtual particle 虚粒子
virtual wave 虚波
void space 虚空
wave of knowledge 知识波

和实生物

三、物理

accelerating field 湮灭
Aeblian local gauge transformation 阿贝尔局域规范变换
amplitude 振幅
angular quantum number 角量子数
annihilation 湮灭
atomic nucleus 原子核
atom 原子
auto-decoherence 自动退相干
average density 平均密度
background radiation 涨落
Bell's inequality 贝尔不等式
big bang theory 大爆炸理论
biology 生物
Bohm's causal theory 玻姆因果性理论
Bohr magneton 玻尔磁子
Bohr radius 玻尔半径
boson 玻色子
box-type normalization 箱式归一化
Brownian motion 布朗运动
catastrophe theory 突变论
catastrophe 突变性
characteristic radius 特征半径
characteristics, feature 特征
characteristic surface 特征曲面
characteristic wavelength 特征波长
charge carrier 电荷载体
charge conservation 荷的守恒
chemistry 化学
circle micro-current 环形微电流
circumference 圆周长
classical electron theory 经典电子论
classical mechanics 经典力学
classical probability 经典概率
classical state 经典态
clock synchronization by light signals 光信号对时
coherence 相干
collapse of wavepacket 被测系统
collapse 坍缩
commutation 对易
Compton matter wave 康氏物质波(康普顿物质波)
Compton momentum 康普顿动量
Compton wavelength 康普顿波长 $\lambda_0(h/m_0c)$
concentration configuration/form 集中形态
conditional probability 条件概率
confidence interpretation 置信度解释
configuration space 组态空间
continuous distribution 连续分布

continuous effect 连续作用
contraction of space time 时空收缩
conversion of image and point [Transformation of image into point] “形-点转换”
cooper electron pair 库柏电子对
coordinate axes 坐标轴
coordinate translation 坐标平移
Copenhagen School 哥本哈根学派
Copenhagen-Von Neumann's interpretation 哥本哈根—冯·诺依曼解释
correlation 关联
cosmic planet 宇宙星球
coupling 耦合
covariant derivative 协变导数
curvature factor 曲率因子
curvature interpretation of quantum mechanics 量子力学曲率解释
curvature model 曲率模型
curvature wave 曲率波
curvature 曲率
de Broglie Wave 德布罗意物质波
decay 衰变
decoherence 消干(退相干)
decoherence 衍射
deexcitation 退激
degree of freedom 耗散效应
derivative 导数
differential element 微元体积
differential 微分
diffraction 衍射
dimension 量纲
discontinuous distribution 非连续分布
discontinuous effect 间断作用
discrete 离散
discretization 离散
disorder 无序
dispersion 弥散
displacement vector 位移矢量
dissipation 耗散
dissipative effect 耗散效应
disturbance 干扰
double-slit interference 双逢干涉
double solutions 双重解
eigenfunction 本征函数
eigenstate 本征态
eigenvalue 本征值
electricfield vortex 电场旋涡
electric field 电场
electromagnetic field 电磁场
electromagnetic force 电磁力
electromagnetics 电磁学
electron pair 电子对
electron transition 电子跃迁
electron 电子
elementary particle 基本粒子
element 元素
energy level transition 能级跃迁
energy level 能级

energy 能量
entangled state 纠缠态
entanglement 纠缠
entity structure 实体结构
EPR imaginary experiment EPR 思想实验
EPR paradox EPR 佯谬
equivalent structure 等效结构
error 误差
Ether 以太
Euclidean space 欧氏空间
excitation 激发
excited state of vacuum 真空激发态
excited state 激发态
external force 外力
external space 外部空间
fermion 费米子
field source 场源
field theory 场论
field 场
final state 末态
flow conservation 流的守恒
fluctuation 涨落
force line 力线
free particle 自由粒子
frequency interpretation 频率解释(频度解释)
frequency 频率
gaseous state 气态
gauge field 线性谐振子
gauge invariance 规范不变性
gauge transformation 规范变换
general image 整体形象
general relativity 广义相对论
geometrization 几何化
ghost field 鬼场
ghost particle 鬼粒子
global gauge transformation 整体规范变换
globality 广域性
global transformation 整体变换
gluon field 胶子场
gluon 胶子
gravitational field equation 引力场方程
gravitational field 引力场
gravitational potential 引力势
gravitation field theory 引力场论
gravity 引力
guided wave 导波
Hilbert space 希尔伯特空间
hydrogen atom 氢原子
hypersurface 超曲面
identity principle 全同原理
“image” of high-level “上形”
“image” of low-level “下形”
“image” “形”
image 影象
infinite deep potential well 无限深势阱
initial state 初态
integral region 积分区域
integral 积分

intensity 强度
interference fringe 干涉条纹
interference wave sources 相干波源
interference 干涉
intermediate boson 中间玻色子
internal force 内力
internal space 内部空间
interpretation of intrinsic probability 内禀概率解释
interpretation of quantum mechanics 量子力学诠释
interpretation 诠释
intrinsic energy density 内能密度
intrinsic energy 内能
isotropy 各向同性
kinetic energy 动能
Lagrangian density 拉格朗日密度
law 定律
light speed 光速
limit value 极限值
limit 极限
linear function 线性方程
linear harmonic osillator 线性谐振子
liquid state 液态
local discretization 局域分离
local gauge transformation 局域规范变换
locality 局域性
local transformation 局域变换
local 局域
logic interpretation 逻辑解释（确认度解释）
long-range force 长程力
Lorentz contraction factor 洛仑兹收缩因子
Lorentz transformation 洛仑兹变换
luminous image conversion [Transformation of image into light] “光一形转换”
machine 机械
macroscopic mass point 宏观质点
magnetic field 磁场
magnetic moment 磁矩
magnetic quantum number 磁量子数
mass density 质量密度
mass-point model 质点模型
mass point 质点
mathematics 数学
matrix 矩阵
matter wave 物质波
measurement of length in gravitational field 引力场测长
mechanism 机理
microscopic mass point 微观质点
microscopic object 微观客体
microscopic world 微观世界
microwave 微波
Minkowski space 闵氏空间
mixed state 混合态
modal interpretation 模态解释

model 模型
molecule 分子
momentum-energy tensor 动量—能量张量
momentum 动量
moving mass 运动质量
multi-dimensional world 多重世界
mutant area 突变区
natural force 自然力
neuroelectrical current 神经电流
neutron 中子
Newtonian mechanics 牛顿力学
Newton's space time 牛顿时空
non-Abelian local gauge transformation 非阿贝尔局域规范变换
noncommutation 不对易
non-local 非局域
normalization 归一化
observation information 观测信息
orbit 轨迹
original "image" in macroscopic 宏观原形
origin of coordinates 坐标原点
orthogonal system 正交系
orthonormalization 正交归一
particle 粒子
periodic function 周期函数
phase circle 相位圆
phase difference 周相差
phase 相位
phase 周相
photon 光子
physical interpretation 物理诠释
physical mechanism 物理机制
physics 物理
physics 物理学
physiology 生理
plane 平面
point electron 点电子
point particle 点粒子
point sphere "点球体"
position 位置
principal quantum number 能级量子数
probability amplitude 概率幅
probability distribution 概率分布
probability interpretation 概率解释
probability wave 概率波
probability 概率
projection 投影
propagation 传播
proton 质子
pure state 纯态
quality carrier 质量载体
quantitative construction of "image" "形"的定量建构
quantum electrodynamics 量子电动力学
quantum entanglement 量子纠缠
quantum entropy 量子熵
quantum field of ground state 基态量子场

quantum field 量子场
quantum fog 量子迷雾
quantum measurement 量子测量
quantum mechanics 量子力学
quantum number 量子数
quantum of action(h) 作用量子
quantum potential 量子势
quantum probability 量子概率
quantum probability 量子概率
quantum properties 量子特性
quantum space time 量子力学时空
quantum 量子
quark 夸克
radial wave function 径向波函数
radius of curvature 曲率半径
radius 半径
reference curvature, base curvature 基准曲率
reference 参照物
relative-state interpretation 相对态解释
relativistic mechanics 相对论力学
relativistic spacetime 相对论时空
resonance curve 共振曲线
resonance peak 共振峰
rest energy 静能(m_0c^2)
rest mass 静止质量
Riemannian space 黎曼空间
rule 规则
scalar potential 标势
Schrodinger's cat 薛定谔猫
scientific community 科学共同体
self-energy 自能
self-entanglement 自纠缠
self-interference 自相干
sensate object 可感物
singal value 单值
singlet "单态"
singularity 奇点
solid state 固态
space entanglement 量子纠缠
spacetime 时空
space 空间
spatiotemporal dynamics 时空动力学
spectral line 光谱线
spherical curvature 球面曲率
spin moment 自旋磁矩
spin quantum number 自旋量子数
spread point 涂抹的质点
state function 态函数
state parameter 状态参量
state 态
state 状态
static energy 静能
static particle 静态粒子
statistical interpretation 统计解释
statistic ensemble interpretation 统计系综解释
stochastic event/random event 随机事件

stochastic process interpretation 随机过程解释
strong-charge carrier 强荷载体
strong interaction 强相互作用
structure function 结构函数
structure space 结构空间
structure wave “结构波”
superconductivity 超导
superfluid 超流体
superposition state 叠加态
superstring 超弦
surface curvature “表面曲率”
symmetric destruction in vacuum 真空对称性破缺
symmetry 对称性
target 靶
tested system 被测系统
the characteristics of space time 时空特征
the curvature of space time 时空弯曲
theory of relativity 相对论
the quantum theory of field, quantum field theory 量子场论
the scheme of “clock synchronization of trains” “火车对时”方案
the structure of matter 物质结构
the treatment of decoherence 退相干处理
three dimensional time-space 规范不变性
time-space blindness 时空盲区
time 时间
topological type 拓扑类型
two-level branch 两能级分支
uncertainty principle 测不准关系(测不准原理)
uniform flat space time 均匀、平直时空
uniform motion 匀速运动
universal gravitation 万有引力
universal joint 万向节
vacuum 真空
vector potentiol 矢势
vibration mode 振动形式
virtual matter and real space 物虚空实
visibility interpretation 可视度解释
volume density 体密度
volume element 体积元
wave equation 波动方程
wave function, wavefunction 波函数
wavelength 波长
wavelet 子波
wave particle duality 波粒二象性
wave 波动
weak-charge carrier 弱荷载体
weak-coupling 弱耦合
weakly interaction 弱相互作用
Yang-Mills gauge field 杨—米尔斯规范场